A MANUAL

OF

ELEMENTARY BOTANY FOR INDIA

BY

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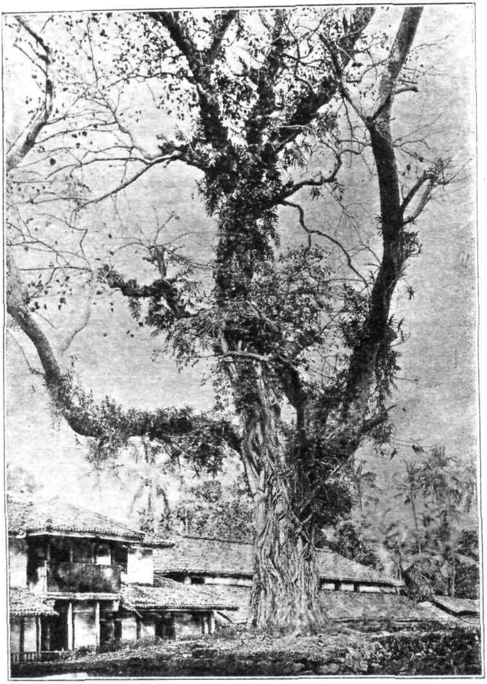

Epiphytes growing on Ficus religiosa.

222, 226, 228, 229, 230 to 232, 234, 235, 238, 239 to 241, 243, 249, 267, 286, 287, 292 to 295, 298, 338, 350, 351, 355, done by R. Srinivasa Ayyar, artist of the Government Entomologist) were made by my artist, M. N. Chinnaswami Pillai, and great credit is due to him for the careful drawings of sections made from under the microscope: the photographs and photomicrographs were taken by me.

I am indebted to Mr. R. C. Wood, M.A., for reading through the greater portion of the manuscript and the proof and also for many useful suggestions. I have also received much help in proof reading from my Chief Assistant Mr. C. Tadulingam, F.L.S., and from Mr. P. S. Jivanna Rao, B.A., Teaching Assistant, in the preparation of glossary and index to plants. Lastly, I have to express my deep gratitude to Mr. D. T. Chadwick and the Hon'ble Mr. Ll. E. Buckley for encouragement to write the book and the Madras Government for ordering its publication. I must also thank Sir Alfred Bourne and Lady Bourne for encouraging me after going through the earlier chapters of this book in the manuscript.

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COIMBATORE,
1st March 1916.

K. RANGA ACHARI.

PREFACE

ALTHOUGH a large number of excellent books on botany are available, they are not so useful for students of this country because the plants referred to in these books are not known to them, nor are they easily procurable. A few books in which Indian plants are dealt with are either too elementary or they cover only certain aspects of plant life. This book, restricted to flowering plants, is intended to meet the requirements of students of Secondary and Training schools, Technical and Professional Colleges and of teachers and others interested in botany.

The arrangement of the topics adopted is what I found to be most convenient in practice. Most of the facts contained in this book form the common property of botanists, but the material chosen for the elucidation of these facts is new. The use of a microscope for purposes of demonstration is essential for a clear and correct understanding of the subject, although some deprecate its use even in the preliminary courses of the University in this Presidency. No one would ever try to teach the functions of plants such as Absorption, Starch formation and Respiration without reference to root-hairs, Chloroplasts and stomata. Mere mention or even verbal descriptions with diagrams cannot be expected to make points as clear and impressive as the demonstrations of actual things would do. To ensure a clear and correct understanding of even the most simple and fundamental facts of plant life, the use of the microscope for demonstration is an absolute necessity, but its misuse must be prevented and guarded against.

The illustrations were specially prepared for this book. All the line drawings (except figures 176, 205, 209, 211, 221,

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CHAPTER I.

INTRODUCTION.

THE science of botany or the study of plants is undoubtedly one of the most interesting branches of study. A knowledge of plants is of the utmost importance at the present day, and at every turn in our life this will be found useful. Our lives and those of all animals are dependent upon the vegetation of the earth, and yet how few of us realise the importance of the part played by plants!

Plants are found everywhere and there is scarcely an inch of the surface of the globe that is not occupied by one or other of the living plants. They are infinitely varied. There are plants of all sizes, from the minutest speck like the bacteria revealed only by the highest powers of the microscope, up to the trees assuming gigantic proportions. (See fig. 1.)

In form, plants vary so much that one is justified in wondering why we include them all under one group, the Vegetable kingdom. Plants are generally grouped under the two heads, flowering and non-flowering plants. Flowering plants produce seeds and hence they are called *seed-bearing plants* or *spermophytes*. Non-flowering plants do not produce seeds and they are known as *cryptogams*.

A plant is a living, growing organism. No one would ever think of denying this fact, and yet this idea is hardly a prominent one with us. Animals have habits of their own; they like certain things and dislike others; they have very often ways of their own; they breathe, feed and reproduce their own kind, and have to fight with individuals of their class and also with other living beings. Just like animals,

plants also have their habits, likes and dislikes, and little ways of their own; like animals they breathe, eat and reproduce their own kind; they also have much to fight against; and they make the most of every opportunity. However, there exists considerable difference between animals and plants, in their mode of living.

FIG. 1. The main trunk of *Sequoia gigantea*, Lindl et Gord, the Mammoth tree of California. Note the path cut through the trunk. (From a photograph lent by Dr. C. B. Rama Rao.)

Although plants present endless differences in detail, *most of them are alike in certain general features of form and structure*. A cursory examination of seed plants is enough to convince one of this fact. In a plant body we can distinguish two definite parts: the root which penetrates deep into the soil and the shoot which grows upward into the air. The shoot consists of the stem, leaves, flowers and fruits and the root has only branches. These are the conspicuous organs of the plant, and they are concerned in the work of nutrition and reproduction.

A plant grows and lives amidst other plants and animals. There are also the physical conditions such as the soil, the moisture, and the temperature. All these constitute the surroundings of the plant. A successful living, on the part of a plant, depends upon the conditions and the relationship existing between it and the factors which constitute its surroundings. Plants get particular shapes and habits, as the result of the interactions between them and their surroundings.

Plants also like animals have to fight against disadvantages which are generally formidable. They have to struggle against animals and other plants. They must also be capable of seizing upon any advantage that may present itself in the air, in the soil and in competition with other plants. Growth amidst very uncongenial surroundings is not possible, because plants are not able to adjust themselves to them. If, on the other hand, the environment is not very uncongenial, the plant adapts itself by modifications in its structure and habit.

CHAPTER II.

THE TRIBULUS AND GYNANDROPSIS PLANTS.

THE study of plants is best begun by the examination of some of the common ones. All of you have seen and are acquainted with the Tribulus plant. The scientific name of this plant is *Tribulus terrestris*, L.* It grows everywhere in dry open places and is in flower all the year round. Perhaps you remember the tribulation it causes to those who unwarily tread on it.

Try to pull one of these plants from the ground. It is not quite easy to do so. The difficulty of pulling up the root shows one use of this part of the plant, and that is that the root fixes the plant firmly in the ground and prevents it from being dragged out by the wind. The root-system of this plant consists of a single, thick, long root going straight down, and a few small roots springing from it and running obliquely. The roots are all pale in colour. The stout, leading root is called the *tap-root*, and the others are lateral roots. It must not be supposed that these represent the whole of the root-system of this plant. Very many small roots remain behind in the soil.

The main stem of this plant is in continuation with the tap-root and, rising a little above the ground level, it breaks into a number of branches, running on all sides and lying close to the ground. The *shoot* or the aerial part of the plant consists of several stems, bearing leaves, flowers and fruits. The whole of the shoot-system is green, whereas the root-system is devoid of this colour. All parts of the shoot are covered with close-set, soft hairs.

The most conspicuous feature in the shoot is the presence of a large number of green leaves. At the lower portion of the branches, the leaves are larger and they get smaller and

* The scientific name of a plant consists of two words. The first word (Tribulus) is the name of the genus and the second (terrestris) is the name of the species. The letter L. stands for Linnæus who first gave this name to this plant.

smaller towards the apex. This is so, because the leaves nearer the base of a branch are older and those nearer the apex younger. In other words, the leaves arise at the tip one after the other in regular succession.

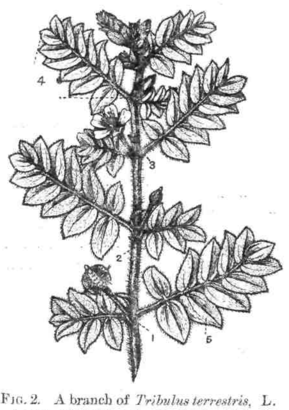


FIG. 2. A branch of *Tribulus terrestris*, L. 1, node ; 2, internode ; 3, stipule ; 4, leaf ; 5, leaflet. (Half the nat size.)

In the stem the places where the leaves arise are called *nodes*, and the portion between two successive nodes is termed an *internode*. Towards the growing end of the shoot, the internodes get shorter and shorter, and hence the leaves get crowded. At every node buds are situated in the angles formed by the leaf with the stem. This angle is called the *axil*. When the bud in the axil develops, it repeats the character of the shoot on which it arises, and so it is called a branch. In flowering plants branches arise generally from the axils of leaves.

At every node in the Tribulus branch, there are two leaves, opposite to one another ; one leaf is smaller than the other and sometimes even this small leaf may be wanting. Four small pieces somewhat triangular in shape are present at every node, one on each

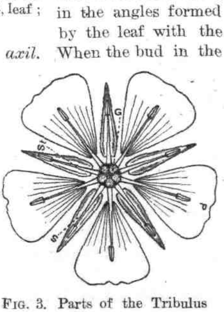


FIG. 3. Parts of the Tribulus flower. S, sepal ; P, petal ; St, stamen ; G, pistil. (Three times the nat. size.)

side of the leaf. These out-growths from the basal portion of a leaf are called *stipules*.

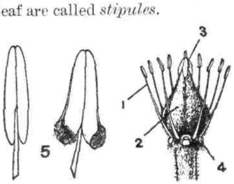


FIG. 4. The essential parts of the Tribulus flower. 1 and 5, stamens; 2, ovary; 3, stigma; 4, gland. (5 ten times and the others three times the nat. size.)

The leaf has a very short stalk called the *petiole*, and the leaf blade is cut up into segments, in such a way that one can be taken off, without in the least affecting the other pieces. Therefore the leaf is a *compound leaf*, and the pieces are *leaflets*.

One may be inclined to consider the leaflets as leaves. But we have very good reasons for calling them leaflets. Leaves spring from the nodes; and the stem which bears them either grows beyond them, or gives sufficient proof that it will do so. Leaves commonly die and fall off as a whole, i.e., petiole and all. If these small segments are really leaves, they must fall one after another leaving the axis on the plant, and the axis must have a growing region at its free end. Leaflets, along with the part carrying them fall down, and there is no growing point at the end of this part. We have, therefore, to consider the whole structure, leaflets and all, as forming a leaf. As a rule buds are found in the axils of leaves and, in the axils of leaflets, we do not find any.

Some of the branches may have bright, yellow flowers springing from the axils of leaves. The flower consists of four distinct parts. The most conspicuous ring of yellow leaves is the *corolla*, and the leaves of this whorl are the *petals*. Between and below the petals, we find five narrow structures green in colour. These are called *sepals*, and the whorl of sepals is known as the *calyx*. In the flower bud, the sepals form a tight coat. Next to the petals inside, there are ten thread-like things with yellow bodies at their ends, and each of these yellow knobs has two lobes. Five of these threads are long and opposite the petals and the remaining five are short and opposed to the sepals. These two whorls

are the *stamens* and each stamen consists of a stalk or *filament* carrying a knob, called an *anther*, at its tip. The anthers contain a fine powder or *pollen*, some of which may be brushed off easily on the fingers. Still inside, in the centre of the flower, there is a five-lobed conical body which is called the *pistil*. This grows and becomes the *fruit*. The top of the pistil is called the *stigma* and the lower dilated portion is the *ovary*. All the parts of the flower spring from the top of the flower-stalk, in close succession. No buds arise from the axils of the floral leaves.

The next thing to consider is whether all the parts of the flower are essential, or only some of them. If we examine flowers at different stages, we do not find all the parts in all of them. Some may have all the parts, but the petals and the sepals may be in a faded condition and about to fall off. In others these parts may be wanting. But in all the flowers, the pistil is sure to be found. This part, instead of remaining small, grows and, therefore, its size will vary according to the stage of development. The pistil is really a young fruit containing very young undeveloped *seeds*. We must consider the parts directly concerned in the production of seeds as the most necessary and essential parts of a flower. The pistil is clearly one of the essential organs, because it contains the young seeds. Stamens are also essential like the pistil, because the seeds are not formed without their help. If we remove the anthers before the flowers open and discharge the pollen and then cover the flower with a paper bag, the pistil falls down. If pollen is deposited on the stigma, the pistil matures and seeds are formed. Therefore we have to infer that the pollen is in some way connected with the production of the seed. So it is evident that the function of the pollen is to cause the production of the seeds by some action which it exerts after it is applied to the pistil. This action leading to the formation of seeds is known as *fertilisation*, and the transfer of pollen to stigma, *pollination*.

The Tribulus fruit consists of four or five lobes, and it breaks up into as many segments. (See fig. 5.) Each of these segments bears at its back a pair of long spines about the middle, and another pair of short spines lower down.

When transversely cut it is somewhat triangular in shape and there are four to six thin flat ovate seeds in each segment. The hard covering with its spines not only affords excellent protection to the seeds, but also helps the plant in bringing about the dispersal of its seeds. When we are hurt by the Tribulus fruit, while walking with bare feet, we get annoyed and pick the fruit and throw it away. This is exactly what the plant needs and partly accounts for the persistency with which this plant grows everywhere.

FIG. 5. Fruit of *Tribulus terrestris*, top view. (One and a half times nat. size.)

As another example, we shall examine the plant, *Gynandropsis pentaphylla*. This is a common weed of cultivated and neglected fields. This plant grows erect, branches freely and the root and the shoot systems are very clearly marked.

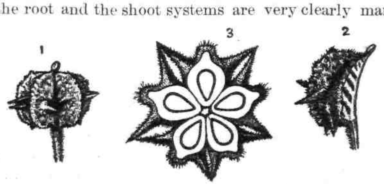


FIG. 6. Fruit of *Tribulus terrestris*. 1, side view; 2, a segment; 3, transverse section. (Nos. 2 and 3 twice the nat. size.)

This distinction into root and shoot is a general character of plants, and it is of fundamental importance.

The root-system of this plant does not differ very much from that of the Tribulus plant. There is a deep seated tap-root, as in the Tribulus plant, and it also bears branches.

The shoot-system of the plant, on the other hand, differs from that of the Tribulus in several respects. The branches rise up and grow erect into the air, instead of lying prostrate on the ground as in the Tribulus plant. The leaves are borne singly at the nodes and they have long petioles. The expanded green blade of this leaf consists of leaflets, but they are arranged in a way quite different from that of

the Tribulus leaflets. All the leaflets are at the top of the petiole, and the arrangement recalls to our mind the palmyra leaf. As the disposition of the leaflets is similar to the arrangement of the main ribs of the palmyra leaf, the

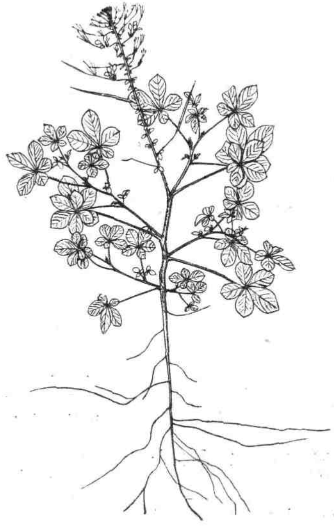


FIG. 7. A complete plant of *Gynandropsis pentaphylla*. (One-sixth of the nat. size.)

arrangement is called *palmate* ; it is also called *digitate*, because the leaflets spread out like the fingers of a hand. The Tribulus leaflets are borne on the stalk like barbs on a feather of a bird, and so the arrangement is said to be *pinnate*.

The flowers are axillary, but the leaves from whose axils flowers spring become very much reduced. All the parts are

present in these flowers. The outermost whorl of calyx consists of four sepals and the corolla of the same number of petals. Both these enveloping organs are close together, and they do not hold the most vital relationship to the formation of seeds, which is after all the most important duty of the flower. The essential organs, the stamens and the pistil, stand out very conspicuously, being borne by a stalk. Both the stamens and the pistil are providedwith stalks of their own.

FIG. 8. The flower of *Gynandropsis pentaphylla*. (Three times the nat. size.)

The Gynandropsis fruit is long and cylindric, and it consists of a wall enclosing a single cavity with three or four rows of seeds.

From a study of these two plants, we learn that plants have different organs doing different functions. Flowers are the organs set apart for the work of *Reproduction* and the other organs are mainly concerned with *Nutrition*. The root-system secures a firm anchorage for the plant and absorbs water whence it passes to the stem. The stem bears the leaves and the flowers, and it is the medium through which the raw materials for food pass. Leaves prepare the food needed for the growth of the plant.

CHAPTER III.

THE SEED AND ITS GERMINATION.

ALL plants begin their life as *seedlings*, which arise from *seeds*. So we shall examine a few common seeds with a view to learn their structure and then follow the process of germination. The seeds of Tribulus and Gynandropsis, though simple in structure, are not so well suited for the purpose, as the seeds of pulses, e.g., *Cicer arietinum*, *Dolichos Lablab*, *Cajanus indicus*, and *Canavalia ensiformis*.

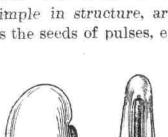


FIG. 9. The profile and broadside view of a seed of Dolichos.

The seed of *Dolichos Lablab* is oval, with a smooth surface and a white streak on one of its sides. At one end of the white streak there is a small pit, which is really a minute hole in the seed coat called the *micropyle*. When we press soaked seeds between the fingers, water will be seen oozing out from the micropyle.

Take a well soaked Dolichos seed and remove with a knife the outer covering or the seed-coat. This covering is really divisible into an inner, thin membrane and an outer, thicker firmer one. The whole mass, now-exposed, is the *embryo* or the young plant. On one of its edges there is a conical protuberance, which is called the *radicle*. With the help of a knife or a needle this mass may be separated easily into two large fleshy bodies, or *cotyledons* (seed-leaves) which are not completely separate from each other, but are connected at the side with the radicle. The end of the radicle fits into a hollow cavity, in the seed-coat, exactly opposite the micropyle. Although the cotyledons fit very closely together, they come apart without tearing, as they are naturally separate.

The structure to which the cotyledons are attached is called the *primary axis*, which by subsequent growth,

develops into a seedling and then, into an adult plant. This axis is really the embryo plant. In it we recognise all the parts of the young plant with the exception that nothing comparable with the cotyledon occurs in the growing adult plant. The cotyledons are really leaves containing reserve food-stuff for the use of the embryo plant when it starts life and begins to grow. The curved end of the primary axis above the insertion of the cotyledons is the *plumule* and the part below the point of attachment is the *radicle*. The plumule consists of a very short piece of stem, on the top of which is the *bud*.

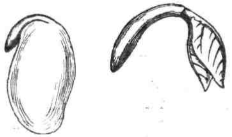


FIG. 10. The embryo and the primary axis in the seed of Dolichos.

When seeds are sown, they soon show signs of life. This manifestation of life is very striking, and changes in form and size take place very rapidly during germination. The early stages in the process of germination can be observed with ease by soaking *Dolichos Lablab* seeds (or other seeds) in water, until they are soft, and then allowing them to germinate in damp sawdust or coconut fibre. The seeds may be taken out, a few at a time, at short intervals, for noting the progress in the process of germination. The process of germination is rapid, if the seeds are kept in a warm room, but even then, some time will probably elapse, before much change is noticeable in them.

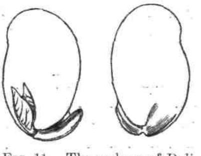


FIG. 11. The embryo of *Dolichos Lablab* seed with one cotyledon removed.

The embryo plant in the seed generally undergoes a period of rest, although this is not absolutely necessary. However it begins to wake up as soon as it is placed under suitable conditions. When placed in the soil seeds absorb water

very rapidly. The gradual absorption of water by seeds is a very interesting process. Place some seeds in water and observe constantly for half an hour and, after that, at frequent intervals. Note whether the soaking affects the size, colour and texture. Does the seed coat wrinkle? If so, the wrinkles indicate the places where water has entered and the way it spreads inside the seed-coat. The wrinkling commences near the white streak (hilum) and so it is obvious that water enters, at first through the micropyle, though later on the entire surface of the seed-coat may absorb it. Further, the line of soft material which runs the whole length of the seed on one side absorbs water very rapidly.

FIG. 12. Seeds of Canavalia showing the wrinkling of the seed-coat.

The cavity into which the radicle fits gets filled with water at the very outset. This water comes into contact with the radicle which grows first, and also very rapidly. The part of the seed-coat beneath the hilum stores up a considerable amount of water for the benefit of the developing embryo. Then the seed-coat and the embryo absorb plenty of water and, in consequence, the seed becomes larger and softer. It is only after this swelling has happened that the seed begins to show any sign of germination. The swelling of the seeds exerts a considerable amount of pressure. This fact can be demonstrated by filling a narrow-mouthed glass bottle with seeds that will just pass through the mouth and placing it in a vessel containing water. After some hours or the next day the seeds would have burst the bottle. (See fig. 13.)

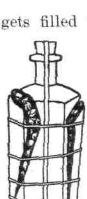


FIG. 13. A glass bottle burst by the swelling of Bengal gram seeds.

The amount of water that seeds, such as *Dolichos Lablab* and other pulses, can absorb is surprisingly large. *Dolichos Lablab* seeds absorb from 95 to 130 per cent of their own dry weight of water: Bengal gram seeds absorb 104 to 110 per cent and Horse gram from 95 to 107 per cent.

Under the influence of moisture and warmth the embryo in the seed begins to unfold its parts. Somewhere close to the micropyle the radicle makes its appearance breaking through the seed-coat, and grows downward towards the centre of the earth, whatever may be the position of the seed.

In germinating seedlings the root grows in length at first and the lateral roots appear only later. This ensures the firm anchoring of the seedling. The next striking feature in the germinating seedling is the elongation of the part of the axis below the cotyledons by rapid growth. At this stage the cotyledons are still enclosed by the seed-coats and so the part of the axis below the attachment of the cotyledons (*hypocotyl*) assumes the form of an arch. The looped hypocotyl by its growth breaks through the soil dragging along with it the cotyledons and the plumule within. This part gradually straightens itself and the cotyledons come out of the seed-coat. The escape of the cotyledons from the seed-coat is important, because the plumule has to find its way out, to grow into the shoot. In seeds in which the cotyledons do not come out of the seed-coat, the plumule emerges through a narrow slit between the stalks of the cotyledons, as in the seeds of Bengal gram, Mango, and *Calophyllum inophyllum*, L. (See fig. 16.)

From the commencement of germination up to the time, when the first green leaves are unfolded, the seedling depends upon the cotyledons for its food supply. At first the cotyledons are fleshy and thick, but as the radicle and the plumule grow, they become softer and thinner and ultimately shrivel up. These, though considered as the first pair of leaves, are thick because they are packed with food for the rest of the growing embryo. Water so eagerly and largely absorbed by the seed, as soon as it is sown, is useful at the very outset to cause the swelling of the seed and later it is used to convey food from the cotyledons to the various parts of the seedling, where growth is actively taking place.

For germination the first condition that is necessary is the supply of water to the seeds. This fact is obvious from our every day experience. An adequate amount of warmth is also necessary. Access of fresh air to the germinating seeds is another essential condition. The need for oxygen is not so much recognised by us as the other two conditions. But when we place soaked seeds in a bottle containing carbon dioxide or hydrogen gas, they do not germinate, although there may be sufficient warmth and moisture.

The behaviour of the embryo during the process of germination and its dependence on the supply of oxygen for successful growth are sufficient indications that we are dealing with living organisms. This becomes all the more apparent, when we observe that the oxygen of the air is absorbed and in its place carbon dioxide is found. And this is exactly what happens in the breathing of an animal. All plants, like animals, must respire so long as they continue to live. As the process of respiration is one of slow combustion, heat is produced both in animals and plants. But the heat produced during the process, in the case of plants, is lost rapidly on account of the very large surface they possess.

That germinating seeds are actively respiring may be demonstrated by means of a very simple experiment. Secure two bottles with wide mouths or conical flasks. Place inside one of them a few germinating seeds of *Dolichos Lablab* and close it with a well fitting cork or rubber stopper having two holes. Close in the same way the mouth of the other bottle or flask, after placing in it some Dolichos seeds killed by boiling or by other means. Insert through one of the holes in the cork a thistle funnel tube, so that the end of the tube reaches almost the bottom of the bottle. Pass

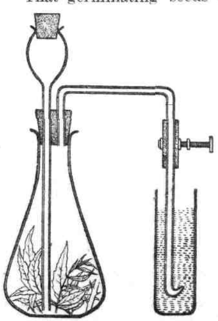


FIG. 14. Apparatus to demonstrate the respiration of twigs or germinating seeds.

into the other hole a bent tube so that the end of the tube is on a level with the inner surface of the cork. Close both the funnel and the free end of the bent tube so as to prevent the air from getting into the bottle. (See fig. 14.) After the lapse of a few hours (from 3 to 6 hours) connect the free end of the bent tube with another tube and dip it in a glass vessel containing lime or baryta water. Then pour water into the funnel to drive the air into the vessel of lime or baryta water. As the air bubbles through, the clear water begins to turn turbid and milky. This does not happen in the case of the bottle containing dead seeds. This milkiness is, of course, due to the precipitation of chalk (or barium carbonate) formed by the combination of carbon dioxide with the lime or baryta water, and it is obvious that the carbon dioxide has come from the germinating seeds.

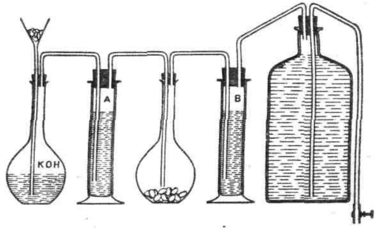


FIG. 15. Apparatus to show that germinating seeds respire.

By using a different set of apparatus it may be shown that germinating seeds give out carbon dioxide even when air freed from this gas is supplied to them. Take a flask provided with a well fitting rubber stopper having two holes. Place in it a few germinating *Dolichos Lablab* seeds along with a few pieces of clean wet blotting paper. Connect this flask with two cylinders containing lime or baryta water by means of bent tubes as shown in the figure. (See fig. 15.) Next connect the cylinder on the left (A in the figure) with a flask or cylinder containing a saturated solution of caustic potash and solid sticks of the same substance arranged as shown in the figure. The glass cylinder on the right side (B in the

figure) should be connected with an aspirator bottle filled with water. All the connections made by glass tubes and rubber stoppers must be made perfectly air-tight. If water is allowed to flow from the aspirator bottle, air will be drawn in through the bottle containing potash and all the carbon dioxide in the air will be absorbed by the potash. The air thus deprived of the carbon dioxide will get into the flask containing germinating seeds. The lime or baryta water in the cylinder interposed between the seeds and the potash solution remains perfectly clear, whereas the baryta water in the cylinder lying between the aspirator and the germinating seed becomes milky. After a time the milkiness increases. It is needless to point out that the carbon dioxide has been evolved by the germinating seeds.

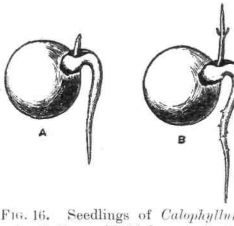


FIG. 16. Seedlings of *Calophyllum inophyllum*. (Half the nat. size.)

The process of germination of the seeds of *Dolichos Lablab* described is quite characteristic of most seeds. However, we meet with variations, especially in the escape of the parts of the embryo from the seed-coat. So we shall study the germination of some other common seeds.

In the Mango plant the seed is enclosed by a hard shell which splits on one side and the radicle comes out through the slit. The cotyledons are very large and are so gorged with food stuff that they have

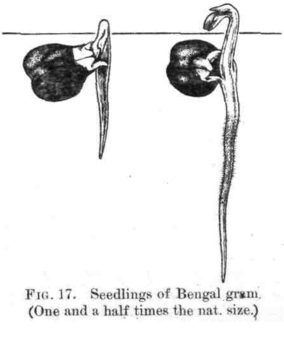


FIG. 17. Seedlings of Bengal gram. (One and a half times the nat. size.)

lost the power of acting as leaves and are unable to come out of the hard shell. The plumule manages to escape through a small slit lying between the cotyledons at their base. Another example of this sort is furnished by *Calophyllum inophyllum*. The seed is enclosed by a hard shell as in the case of the Mango seed and the escape of the plumule also is exactly the same as in it. In the Bengal gram seed we have an instance of a seed remaining underground during germination. The plumule alone escapes from the seed-coat, finding its way between the cotyledons at their base. The plumule has in all these cases to come out through a narrow slit, and so the formation of leaves is very much delayed. The first few leaves, therefore, are not well developed ones ; they are small and are called " scale-leaves."

In the Pumpkin seeds the radicle emerges through a small slit at the narrow end. The cotyledons cannot come out unless the slit becomes wider, because they are large. The radicle develops, close to the narrow end of the seed, a swelling which, like a peg, keeps down the lower half of the seed-coat and the other half is forced upwards by the cotyledons. Then the cotyledons come out, become green, grow and behave like ordinary leaves.

FIG. 18. Pumpkin seedling.

The Castor seed presents special features both as regards its structure and the process of germination. The seed-coat is thick, hard and polished, and at one end of the seed is seen a spongy outgrowth *(caruncle)*. The micropyle is not visible as it is hidden by this outgrowth. After removing the seed-coat we find a mass and if we split this lengthwise in the plane of the flat side, we find a thin leaf-like structure lying flat on each of these massive parts. These are the cotyledons and they are connected with a very small peg-like structure, the axis. The part on which the cotyledons are lying is something

new and it is called the *endosperm*. This is really food stored outside the embryo and it is intended for its use.

FIG. 19. Front and back view of Castor seed.

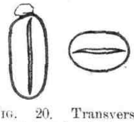


FIG. 20. Transverse and longitudinal sections of Castor seed.

FIG. 21. The embryo of Castor seed with the pieces of endosperm one on each side.

The cotyledons are for this reason thin, and they absorb the food from the endosperm. They remain within the endosperm until all the food store is exhausted and then they come out, expand and behave like green foliage leaves.

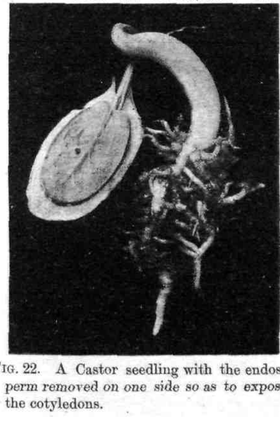


FIG. 22. A Castor seedling with the endosperm removed on one side so as to expose the cotyledons.

The Maize grain may be considered next. It is a single-seeded *fruit* and not a seed. The embryo lies on one side of the grain, and it may be exposed completely by the removal of the thin skin. The embryo consists of a straight cylindrical

axis (the primary axis) and a single cotyledon in the form of a shield folded over the axis. The primary axis is attached at its back to the cotyledon. The plumule is towards the broader end of the grain and the radicle is on the lower narrow side. The free end of the radicle is covered by a special sheath, the *root-sheath*. The cotyledon or the *scutellum* as it is called, is never freely expanded, and one surface of it lies in close contact with the endosperm and, therefore, acts as an absorbing organ. During germination the radicle comes out first, breaking through the root-sheath, and grows downward, while the plumule with its succession of unsheathing leaves goes upward.

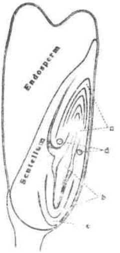


FIG. 23. The Maize grain and its structure. *a*, plumule: *b*, radicle: *c*, root-sheath: *d*, adventitious roots. (Four times the nat. size.)

As further examples we may examine the grains of Cholam, Cumbu and Paddy. In all these cases the greater portion of the grain is occupied by the endosperm and the embryo occupies comparatively a very small space. Though smaller in size and different in shape, these are like the Maize in structure and in the method of germination.

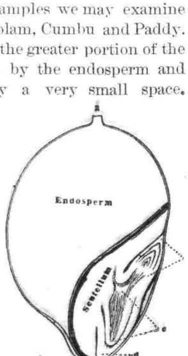


FIG. 24. Longitudinal section of a grain of Cholam. *a*, style scar; *b*, plumule; *c*, radicle; *d*, root-sheath. (Twenty times the nat. size.)

The emergence of the seedling from the soil is an interesting process. In the case of the Dolichos seedling, as well as in seedlings whose cotyledons come up into the air (and hence called *epigeal*), the part of the axis lying below the attachment of the cotyledons or the hypocotyl, as it is called, grows very rapidly and comes out in the form of a loop dragging along with it the cotyledons and the plumule. The loop being strong is able to pierce

through the soil. After sometime the cotyledons reach the surface of the soil, and then they open to allow the plumule to grow.

There are seedlings whose cotyledons always remain underground *(hypogeal)* and in such cases the hypocotyl

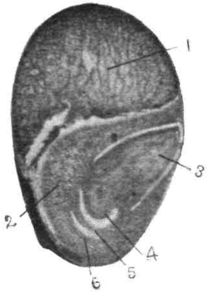


FIG. 25. Longitudinal section of a grain of Cumbu. 1, endosperm; 2, scutellum or cotyledon; 3, plumule; 4, radicle; 5, root-cap; 6, root-sheath. (Magnified about thirty times.)

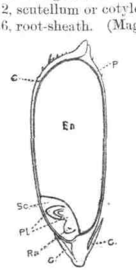


FIG. 26. Longitudinal section of a Paddy grain. *G*, glumes; *P*, palea; *En*, endosperm; *Sc*, scutellum; *Pl*, plumule; *Ra*, radicle. (Ten times the nat. size.)

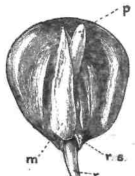


FIG. 27. Maize seedling. *m*, membrane covering the embryo consisting of pericarp and seed-coats; *p*, plumule; *r*, root; *r.s*, root-sheath. (Four times the nat. size.)

never grows: the plumule manages to come out of the seed-coat through a small slit at the base of the cotyledons. (See figs. 16 and 17.) As the plumule has to push aside the soil particles and small stones, its free end is pointed.

The seedlings of Maize and other grains mentioned already and those of Crinum behave in a manner somewhat similar to that of the hypogeal seedlings. The cotyledon in all these never leaves the seed, and the plumule grows out pushing the soil, and this is the reason why the free end of the plumule is pointed. The radicle grows out and the first root bursts the root-sheath and grows downward. New roots arise from the axis and they grow vigorously bursting through the roots-heath and very soon attain the size of the first formed root. In the case of the seedlings of Dolichos, Castor and other seeds that have two cotyledons, all the roots arise from the first formed root and none from the axis. Roots arising from the axis and not thus confined to the first root are called *adventitious roots*. So the roots of the seedling of Maize and other grains are

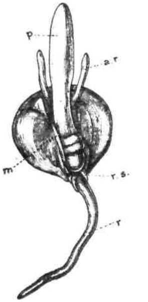


FIG. 28. Maize seedling. *r*, root; *r.s.* root-sheath; *m*, membrane; *a.r*, adventitious-roots; *p*, plumule. (Three times the nat. size.)

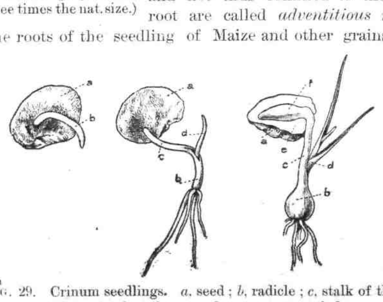


FIG. 29. Crinum seedlings. *a*, seed; *b*, radicle; *c*, stalk of the cotyledon; *d*, plumule; *e*, endosperm; *f*, cotyledon.

adventitious. New roots make their appearance even in the seed stage in the case of the Maize grain. (See fig. 23.) But in the case of the Dolichos seedlings and others having two cotyledons, *the first root invariably gives rise to the whole* of the root-system under normal conditions.

The food stored in the seed, either as endosperm or in the cotyledons, is mostly in the form of starch. If slices of cotyledons or longitudinal sections of any grain are placed in an aqueous solution of Iodine, the former become completely blue and in the latter the endosperm alone turns blue. This is the test for starch. The embryo in the seed or grain does not turn blue, and so it is clear that there is no starch in it.

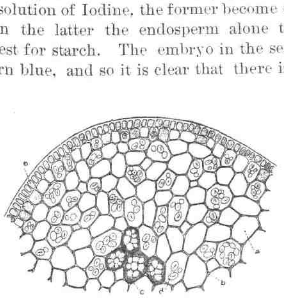


FIG. 30. Section of the cotyledon of *Dolichos Lablab* highly magnified (about 200 times). *a*, empty cell; *b*, cell-wall; *c*, protoplasm; *d*, starch grains; *e*, aleurone layer.

To make out the nature of the reserve food material stored in the seed either in the cotyledons or as endosperm, it is necessary to make use of the microscope. We should take thin slices of the cotyledon or the endosperm and examine them under the microscope. On examining these slices it will be seen that the cotyledons and the endosperm consist of small compartments of various shapes and sizes. These compartments are called *cells*. All these cells will be found to be full of some ellipsoidal bodies. These bodies are the starch grains. Some cells are likely to be free from these grains, and, by examining such cells, it would become obvious that a cell consists of a firm cell-wall enclosing a cavity filled with some semi-transparent granular, reticulated substance called *protoplasm*.

All the activities in the living organisms that we observe are due to this substance, and so it is sometimes called the "*Physical basis of life.*" To make out the structure of a cell and its contents clearly, it would be better to examine under the microscope the hairs found on the young, tender portions of the stem of a Pumpkin plant. The appearance of a single hair of this plant is figured here. The appearance of the protoplasm varies with the age and development of the cell. The cells of the hair of a Cucurbita plant figured here may be taken as an example of a typical, fully grown, mature vegetable cell. Within the cell, the protoplasm is in the form of a net-work. A portion of this substance remains as

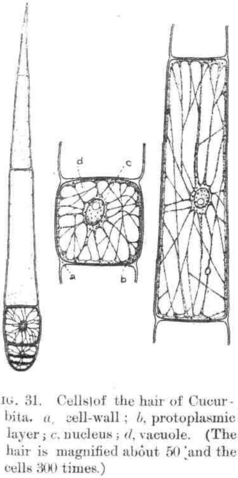


FIG. 31. Cells of the hair of Cucurbita. *a*, cell-wall; *b*, protoplasmic layer; *c*, nucleus; *d*, vacuole. (The hair is magnified about 50 and the cells 300 times.)

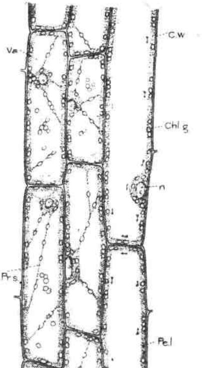


FIG. 32. Cells of the leaf of *Vallisneria spiralis*. *chl. g.* chlorophyll grain; *c.w.*, cell-wall; *n.* nucleus; *Pe. l*, peripheral layer of protoplasm; *Pr.s*, protoplasmic strands; *Va*, vacuole. × 300.

a continuous layer lining the interior of the cavity and adhering closely to the cell-wall without leaving any

space. Several threads, some fine, others coarse, are stretched across in various directions from the layer lining the cell-wall. The spaces within the protoplasm are filled with cell-sap and these spaces are called *vacuoles*. Somewhere within the cell, either in the peripheral layer, or in the cavity, a somewhat rounded compact body will be seen. This body is called a *nucleus*. From the nucleus several strands run to the peripheral layer. As further examples for cells showing the protoplasm to the best advantage, the staminal hairs of Cyanotis and the longitudinal sections of a fresh leaf of *Vallisneria spiralis* may be examined. Both these are figured here.

As has been pointed out already the major portion of the reserve food stuff stored in most seeds is starch. In the seed we do not find starch in the embryo, although there is plenty of it in the endosperm or the cotyledons. But soon after germination we find starch in the seedling, in the axis. So it is evident that starch has somehow been transported to the axis. This substance cannot be transported as such, because it is insoluble in water. Unless this is rendered soluble in water it cannot pass into the axis.

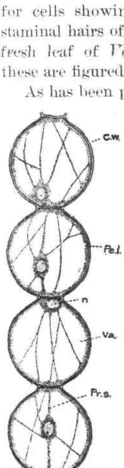


FIG. 33. Cells of the staminal hair of Cyanotis. *c.w*, cell-wall; *n*, nucleus; *Pe.l*, peripheral layer of protoplasm; *Pr.s*, protoplasmic strand; *Va*, vacuole. × 300.

The protoplasm in the cells of the cotyledons remains in a dormant condition, until water has access to it. As soon as water comes in contact with it, it wakes and begins to show its activity. When once it begins to be active it continues to be so without stopping until the cells become dead.

One of the results of the activity of the protoplasm is the formation of a peculiar substance called *diastase*. This substance has the power of converting starch into a soluble sugar. During germination the protoplasm in the cells of the cotyledons produces diastase, and this

acts on the starch grains and corrodes them little by little converting them into sugar. If we examine the starch grains in the neighbourhood of the cotyledons in the Maize or other grain, we find several of them corroded. (See fig. 34.) The

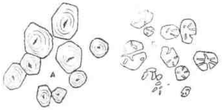


FIG. 34. Starch grains from the endosperm of the Maize grain. A. entire grains; B. corroded grains. × 400.

sugar thus formed from the starch by the action of diastase passes as a solution, from cell to cell, until it reaches the cells in places where growth is taking place. The cells in the actively growing radicle and the plumule use up this sugar, to make good the loss due to the process of respiration.

A plant, like other living organisms, needs proteids to grow and so, besides starch, it should be supplied with this substance. In all seeds, in addition to starch, there will be found some amount of proteid stored in the form of small or large grains. In most cases it lies side by side with

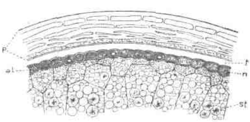


FIG. 35. Aleurone layer in the grain of Cholam. *St*, starch; *al*, aleurone layer; *t*, testa; *n*, nucleus; *p*, pericarp. × 100.

starch as minute particles, and then they can be detected only by special means. Sometimes the substance is confined to a special layer of cells lying outside the endosperm, especially in the case of grains. This layer is termed the *aleurone layer*, because the proteid masses are called *aleurone grains*.

The aleurone grains are particularly striking in the endosperm of the Castor seed. They exist as oval or round

bodies, varying in appearance according to the medium in which it is mounted for observation under the microscope. When the section of the endosperm is mounted in oil the aleurone grains appear as transparent ovate bodies ; a small rounded body is seen either at one end or on it, as shown in

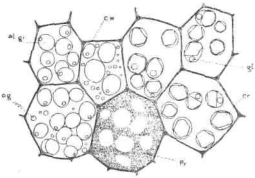


FIG. 36. Aleurone grains in the endosperm of Castor seed. *c.w.*, cell-wall ; *cr*, protein crystal ; *gl*. globoid ; *al.gr*. aleurone grain ; *o.g*. oil globules ; *Pr*. protoplasm. × 400.

the figure. (See the three cells to the left in fig. 36.) If viewed in water then within the body a crystal is seen. This is really the proteid. (See the three cells to the right in fig. 36.)

The reserve food does not always take the form of starch. It may be stored in various forms. In the Castor seed it takes on the form of an oil ; it may be stored as sugar ; and in rare cases it is stored even as cellulose, a substance of which the cell-walls are composed. This is the case in Date seeds.

CHAPTER IV.

THE ROOT.

ONE end of the primary axis of the embryo bears leaves, and it invariably grows upwards and comes above the ground, whereas the opposite end bears no leaves and it persistently goes downward into the soil. This descending part is the root and the ascending portion is the shoot. The first root is merely the extension of the lower end of the primary axis of the embryo plant: it very soon grows, develops branches, and ultimately there will be a well developed root-system.

To follow the gradual development of the root-system, it is necessary to be constantly examining the root. One of the best methods of observing the gradual growth of the root-system is to sow seeds of different plants in a box provided with a sloping glass on one side. The seeds of *Dolichos Lablab*, Castor, Maize, Ground nut and Bengal gram may be sown with advantage, in the seedling observation box. The roots will grow close to the glass pane in the box, and so their growth may be observed with perfect ease, and without in the least affecting the roots. In the case of *Dolichos Lablab* seedlings growing in this box the tap root grows downward, and when it is about two inches long, branches arise upon it, similar in all respects to the main root itself, but thinner. The branches grow away from the primary root almost at right angles to it. More branches arise, and these grow out obliquely from their parent roots,

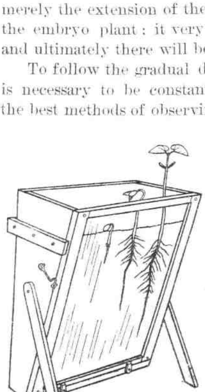


FIG. 37. A seedling observation box with sloping glass front.

and this process of branching may go on until a very extensive collection of roots is produced, which constitutes the *root-system* of the plant.

The branches in the root-system arise in a regular acropetal succession and in the *Dolichos Lablab* seedling the branches spring from the main or tap root in four longitudinal rows around the tap-root.

In the Dolichos Lablab seedlings, as well as in other seedlings, the young tap-root and its branches are covered with downy root-hairs at a short distance behind the young tips.

The root-system differs from the shoot in several respects. The shoot consists of a main axis bearing two kinds of lateral members, branches and leaves. The root-system, on the other hand, consists of a tap-root bearing only lateral roots. The lateral shoot begins as a bud standing in the axil of a leaf, and the axillary bud is a superficial outgrowth from the main axis. Further every main and lateral branch ends in a bud at the free end. The lateral roots do not arise as buds

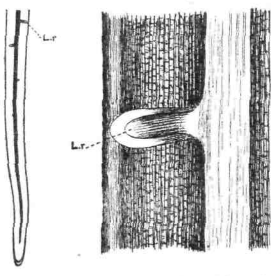


FIG. 38. Section of a root to show the origin of lateral roots. L.r., lateral root.

from the outer portion, but they spring from the deep seated parts of the main root and push themselves out. The free ends of all roots are covered by *root-caps*.

Although roots do not bear buds normally they develop adventitious buds when injured. If the old underground

roots of a Peepul, or Margosa, or *Odina Wodier* are severed from the main root, buds spring up from the cut ends of the severed pieces. These are called *root-suckers*.

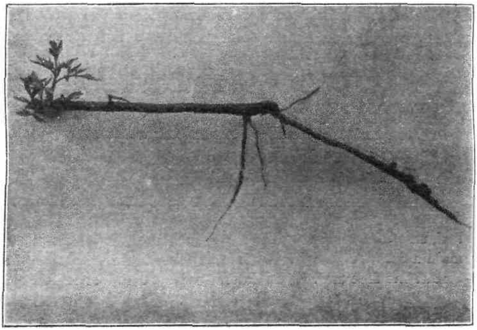


FIG. 39. Root sucker of Margosa. (One-tenth the nat. size.)

In most cases, the root consists of a leading tap-root bearing branches. The primary root may be the leading root or its place may be taken up by some other lateral root. The root-systems of plants vary very considerably in extent, and in all cases the total length of the roots is very much greater than what is naturally anticipated. The root-system of a Paddy plant, for instance, will be several yards in length, when the roots are placed end to end. According to the investigations of certain botanists the root-system of an oat plant measured 150 yards in length, although the spread of the root-system was only a cubic yard or two. The root-system of a Pumpkin plant is said by Nobbe to have measured 5 kilometres (about 5,000 yards).

The nature and extent of the root-system depends largely upon its environment. The texture of the soil and the amount of moisture in it are the factors that affect the evelopment of the root-system. Plants growing in a very

compact heavy ground cannot be expected to have a very extensive root-system, but in open loose sandy soil it will be very much larger.

In young plants like those of *Dolichos Lablab* all the roots of the root-system arise from the tap-root and the branches connected with it, and they do not normally spring from other parts. There are, however, a large number of plants that get their roots from parts other than the tap-root. For instance, numerous roots grow from the nodes at the base

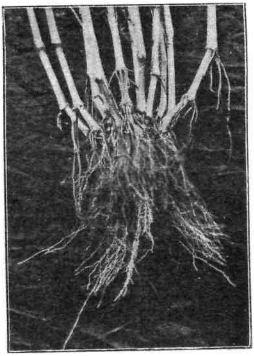


FIG. 40. Adventitious roots.

of the stem of the Cholam plant. All such roots are of the same size and they are called *adventitious* roots. All grasses, the Banyan and the Pandanus trees have roots of this sort. Adventitious roots do not arise in acropetal succession. They are best adapted to utilise food materials from the upper layers of the earth, as the roots are small and equal.

Plants like other living organisms must take in food to enable them to live. They get their nourishment, partly from the soil and partly from the atmosphere. The most

important work the *root* has to perform is the absorption of water from the soil. To enable the root-system to absorb water, which is one of the most important of the food materials used by the plant, the plant should be firmly fixed in the soil so that it may not be upset easily. This work of anchoring it to the soil effectively is also one of the functions of the root-system. All parts of the root-system are concerned in the work of fixation. The tap-root gives support by going straight down and the lateral roots go in all directions around the tap-root and the smaller roots also do the same: *even the very delicate root-hairs help the root in* fixation. The soil particles adhere to the root-hairs so firmly that they constitute numerous holdfasts.

It is easily demonstrable that the root-system is an organ of support. Choose two or three well grown potted plants of about the same height. Cut through the *main root of one* or two without in any way interfering with the other roots. This will obviously necessitate the planting of a stick or other support to keep the plants erect. For the firm anchoring of the plant in the soil a straight deep root is best suited. Pulling up plants having shallow root-systems is quite easy, whereas deep-rooted plants are very hard to pull.

The other function of the root-system, the absorption of water, becomes obvious if we leave off watering the potted plants and water the plants whose tap roots are severed. In both cases leaves drop off and the plants suffer.

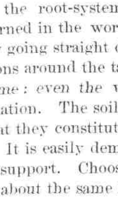


FIG 41. Seedlings fixed to a cork with roots in different directions

If the root is to do its function properly it should grow towards and into the soil. The tap-root has always a tendency to go downwards. Pin to the lower side of the cork of *a bottle a few seedlings in different* directions and replace it as shown in the figure, after pouring some water into the bottle to keep the air moist. After a few hours, the roots in all the seedlings will be seen *growing* downwards. Change the position of the seedlings at frequent

intervals and observe the roots. Even then the behaviour of the roots will be the same. This movement takes place under the influence of gravity.

Roots are also sensitive to moisture. When the roots in their downward and lateral course come to a dry region, they turn away from it and go towards the part of the soil where there is moisture. In water channels, tanks and wells that do not get dry, we generally see roots in abundance. These roots are those of the trees and shrubs growing in the neighbourhood. As roots are sensitive to water we find roots of plants in wells, rivers and channels. By a very simple arrangement it is possible to demonstrate the sensitiveness to water exhibited by the roots. In a seedling pan place a small flower-pot, right in the middle, and sow soaked seeds in the seed pan all round the flower-pot at a distance of one or two inches. Fill the flower-pot with water. When the seedlings have grown well and have produced one or two leaves, lift the flower-pot and you will see the roots of the seedlings. They all come to the flower-pot because it contains water. For success in this experiment the seedlings should not be watered except when the seeds are sown, and even then very sparingly.

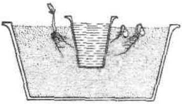


FIG. 42. Arrangement of pots and seedlings to demonstrate the sensitiveness of roots to moisture.

The combined effect of gravity and moisture on the root-system is to make the roots branch well and go in all directions in the soil. Plants that have long tap-roots will last a good while. As the roots produce branches at different heights, they are able to obtain water and salts at different levels. Further the main root goes on growing, and it ultimately stretches a long way down, so there is not much fear of its completely drying, except during a severe drought.

The root must have a structure adapted for the work it has to do. All roots have a central region which consists of long, fine, hard stringy pieces. The root has not only to fix

the plant firmly but has also to stand much pulling, when strong winds blow the stem on all sides. To be able to resist the pull a hard central core is necessary. A rope should have a strong core, if it is to be used for resisting a heavy strain or a pull lengthwise. If the central portion were to be weak it would break.

Internal structure of roots.—The first root, as well as the lateral roots developing later, possesses a growing root-tip. In all roots, whether main or lateral, these growing tips are smooth for a considerable distance. A little behind the growing tips, the roots are completely covered by downy root-hairs to a certain distance; above this region, these hairs disappear and only remnants of dead ones are visible. The actual root-tip is covered by a *root-cap* which consists of a number of layers of cells. In most cases the structure of the root-cap, as well as its presence, can only be made out with the help of the microscope. However, there are a few instances of roots in which the root-cap can easily be seen with the naked eye, as in the aerial roots of Pandanus and Banyan.

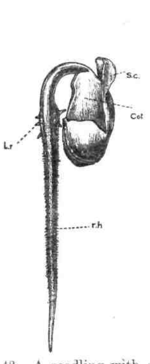


FIG. 43. A seedling with a tap-root covered with root-hairs. *Cot.*, cotyledon; *l.r.*, lateral root; *r.h.*, root-hair; *s.c.*, seed-coat.

The actual tip of the root is composed of small cells, cubical in shape and filled with granular protoplasm, in which is embedded a pretty large round body. This is the *nucleus*. Wherever we see protoplasm we expect to find this nucleus within it. In the cells found at the growing tips, the nucleus is generally more prominent than in the cells found elsewhere. In these tips of roots division of cells is always taking place. As the cells are always actively dividing in this part it is called the *growing point* of the root,

Inasmuch as we find a group of cells all alike in form and doing the same kind of work, we may call these cells of the *root-tip* a tissue and, as it adds to the number of cells, it is spoken of as *meristem tissue*. Further back the cells become larger in all directions and especially so *in the longitudinal direction*. The protoplasm filling the cells, instead of being compact, becomes somewhat loose in structure by having a number of small spaces inside. *These spaces are called vacuoles* and the protoplasm is said to be vacuolated. The root-tip, which is smooth and devoid of root-hairs, really consists of the two distinct parts, the *formative region* covered by the root-cap and the *elongating region*.

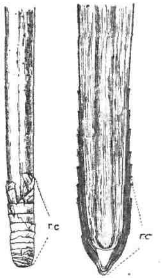


FIG. 44. Root-tip of Pandanus with root-cap *r.c* The right hand figure is a longitudinal section.

The cells of the young root-tip are all living cells filled with protoplasm, and so they are in need of oxygen for their growth. For the admission of the air, spaces are formed between the cells. These spaces appear as dark streaks under the microscope between the lines of cells. At first the cells get separated at some point, i.e., at the angles their walls make with each other. These small spaces become united so that intercellular passages run among the cells of every region, and they are of different dimensions in different areas. These intercellular passages become open to the exterior in the

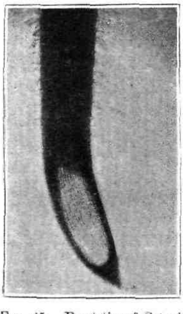


FIG. 45. Root-tip of *Setaria italica* × 50.

upper portion of the plant. This enables the air to enter and circulate through the interior of the tissues. The openings existing on the bark to facilitate the entrance and the circulation of air are the *lenticels*.

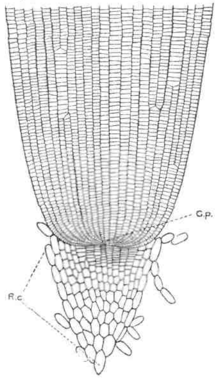


FIG. 46 Root-tip of *Setaria italica* highly magnified. *g.p.*, growing point; *r.c.*, root-cap. The cells are all shown as empty cells with outprotoplasm × 400.

The root-hairs found on the surface of the root a short distance behind the root-cap are long slender outgrowths of the superficial cells. In general, root-hairs have only an ephemeral existence. As the root grows, new root-hairs arise always at the same distance behind the root-tip. Each root-hair consists of a thin wall of cellulose and a protoplasmic layer, and it is brought into close contact with the particles of the soil, as it grows in amongst them. On coming into contact with the soil particles the outer part of the cell-wall becomes changed into a kind of mucilage. So the root-hairs adhere very closely to the soil particles which are always surrounded by films of water.

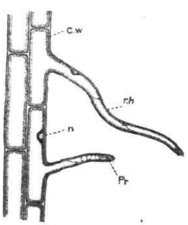


FIG. 47. Root-hairs and their structure. *C.W*, cell-wall; *pr.*, protoplasm; *n*, nucleus; *r.h.*, root-hair. × 400.

Absorption of water occurs only through the root-hairs. The protoplasm and the water inside the root-hair contain

certain substances having a great affinity for water. The cellulose cell-wall of the root-hair is mucilaginous and pervious to water, so the films of water adhering to the soil particles get drawn into the interior of the root-hairs. This absorption of water can take place only under certain conditions: they are access of air, a certain amount of warmth and of course a suitable supply of water.

All substances that have to pass into and out of a plant cell must pass through both the cell-wall and the protoplasmic layer. Pure water readily passes through both the cell-wall and protoplasm. Many substances may pass easily through the cell-wall, but they may not at all pass through the protoplasmic layer. Further the permeability of the protoplasm, even to any one particular substance, is not the same at all times.

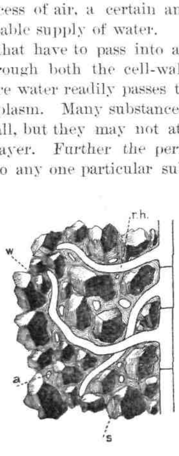


FIG. 48. Root-hairs amidst soil particles. (Diagramatic.) *r.h.*, root-hair; *w.*, film of water; *a.*, air space; *s.*, soil particles.

The water absorbed by the root-hairs passes through the layers lying beneath the root-hair bearing layer *(the piliferous layer)*, and reaches the central core of the root. The cells in the central portion of the root are modified into special structures *(vessels)*, through which water will pass very readily.

The transformation of the cells into vessels specially adapted for conducting the water absorbed begins in the central portion of the root. In older roots, root-hairs are

absent and the conducting tissue (vessels) will be abundant and so the older portions of roots have to be considered as mere conducting portions.

To understand the structure of roots and its adaptation to the functions, it is necessary to examine roots at different heights. As types the roots of Bengal gram, Castor, Cucurbita, Benincasa, Colocasia, Onion, Cholam and Musa, may be examined. The growing regions of roots possess more or less the same kind of structure in all flowering plants. But in the absorbing regions there are differences in structure, and in the conducting regions these differences become still more marked.

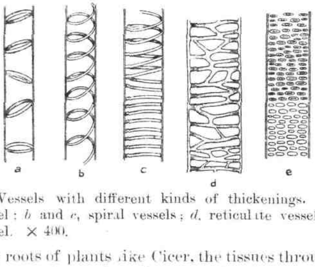


FIG. 49. Vessels with different kinds of thickenings. *a*, annular vessel: *b* and *c*, spiral vessels; *d*, reticulate vessel: *e*, pitted vessel. × 400.

In the roots of plants like Cicer, the tissues through which absorbed water is conducted forms a hard central cylinder surrounded by several layers of cells with thin walls, and this portion of the root is called the *cortex*. The cells in the central portion of the roots increase in number and some of these cells become changed into vessels which arrange themselves in definite groups. These groups run longitudinally and are called *vascular strands* or *vascular bundles*.

These bundles consist of various elements. Some are narrow or wide tubes called vessels and others are thick-walled, elongated or short cells. The vessels are formed from the fusion of the superposed cells; the transverse septa of these cells are absorbed and the thin cell-walls become thickened by the addition of some substance in the form of layers on their inner surface. The thickening never takes

place uniformly. In great many vessels the thickening takes place all over the wall, leaving certain thinner places which we may call pits or pores. The thickening may take the form of a network and in a few vessels the thickened parts are like the rungs of a ladder. There are also vessels with the thickened part in the form of a spiral or isolated rings. Names are given to these vessels according to the nature of the thickening. If the thickening is very pronounced with only a few places not thickened, the vessels are called *pitted vessels*, as the thin areas look like so many pits. The vessels with reticulate thickenings are called *reticulated vessels*. Those with ladder-like thickenings go by the name of *scalariform vessels*; when the thickening is spiral the vessel is a *spiral* one, and if annular it is an *annular vessel*. In a vascular bundle all or some of these kinds of vessels are found and they are all held together by certain fibrous elements which run between them.

If we take the function of the root into consideration we may easily distinguish three distinct zones or regions in the root. They are the extreme tip, the root-hair bearing region and the conducting part. The root-tip is covered at the end by the root-cap, and this is the region where cell division is going on rapidly and also the elongation of the cells. This is succeeded by the zone of the root-hairs, which is the part whose main work is absorption of water. All these regions are not sharply marked off one from the other, but the one runs imperceptibly into the other. In the second absorptive region the beginnings of conductive tissue may also be seen. Lastly comes the conductive region which is really the fully developed portion of the root.

We shall now consider in detail the structure of the roots of some of the plants already mentioned. Let us first study the root of *Cicer arietinum*. A transverse section of this root taken through the growing tip will reveal under the microscope two distinct regions, the central core of cells in which the cells are small, though of different shapes, and the broad outer cylinder enclosing the central core. The outer cylinder, consisting of uniform cells all thin walled and in several layers, constitutes the *cortex*. The central core of tissue is called the *stele*. In the growing region of the tip of

the root the cells in the stele will be remarkably uniform. In the upper part a few cells may be elongated.

In a section taken through the part where the root-hairs are developed, the stele will show some amount of differentiation. The outermost layer of the cortex gives rise to the root-hairs and so, that layer is called the *piliferous layer*.

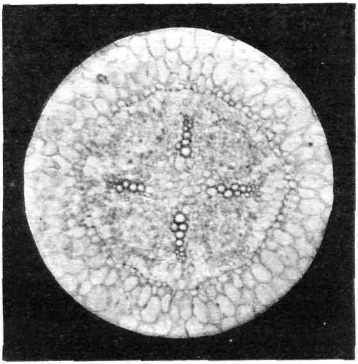


FIG. 50. Transverse section of a very young root of *Cicer arietinum*. The continuous layer of small cells in the form of a ring is the endodermis, and the four groups of thick-walled cells are protoxylem groups. × 400.

All the cells contain protoplasm, except a few thick walled ones which are really the cut ends of vessels. These vessels are confined to the stele and in it they are grouped together in a definite manner. Within the stele we see in the transverse section four distinct groups of thick-walled vessels at equal distances from one another. (See fig. 50.) Of the vessels of these rows, those lying at the periphery of the stele and towards the cortex are smaller and they get gradually larger and larger towards the centre of the stele. From this it is clear that the old vessels are towards the

periphery and the new towards the centre of the stele. In other words, the development of vessels in this case is from the circumference towards the centre. This kind of development is said to be *centripetal.*

The structure of the same root, in a little older portion will be slightly different. The cortex will be quite distinct from the stele or the central cylinder (also called the vascular cylinder, because the vessels appear only within the stele). The innermost layer of cells in the cortex becomes very well marked, and it is termed the *endodermis.* Everything

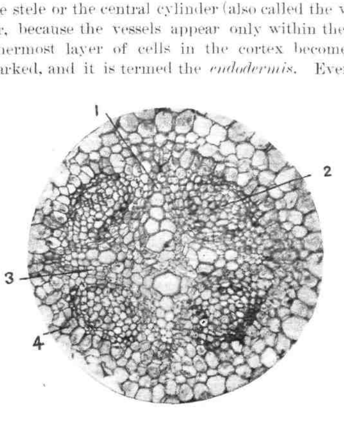


FIG. 51. Transverse section of a very young root of *Cicer arietinum* a little older than in fig. 50. 1, protoxylem ; 2, phloëm ; 3 cambium ; 4 pericycle. × 400.

enclosed by the endodermis forms the stele. Within the stele will be seen the four groups of vessels, which have increased in amount, and have by now all met in the centre (see fig. 52). Alternating with these four groups of vessels, which are called *xylem* groups, there exist four masses of thick-walled cells in the stele, though very close to the cortex. These thick-walled cells are really elongated structures and they are called fibres or *sclerenchyma.* Close to the fibre groups and within the stele we see a few cells irregularly

arranged, and varying in size. Some of these are really thin walled vessels having at intervals perforated transverse partitions. On account of these sieve-like partitions these vessels are called *sieve tubes*. As a large number of sieve tubes are found together in groups in definite situations, these groups are called the *phloëm*. Close to the phloëm we generally find fibre groups. In the stele the peripheral portion lying in close contact with the endodermis and outside the fibre groups is called the *pericycle*. This layer is a very important layer in the case of the root, and it consists of a

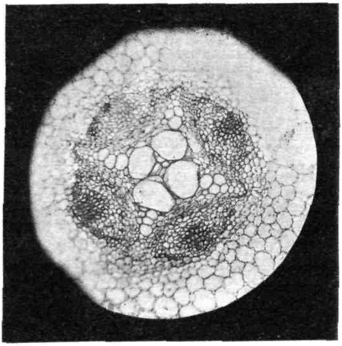


FIG. 52. Transverse section of Cicer root older than in fig. 51. × 200.

single layer of cells, though it may have in certain places more than one layer. Between the xylem and the phloëm groups there are one or two layers of cells quite regular in arrangement, full of protoplasm, broader than long and standing out very distinctly. These are cells undergoing division, i.e., they are meristematic cells. Such meristematic cells as these are also found on the outside edge of the xylem groups, and they are derived from the pericycle. These two groups of meristematic cells become extended and so we see a

continuous ring of meristem. This wavy ring is called the *cambium ring*.

The function of the cambium ring is to produce cells, both inside (towards the xylem) and outside (towards the phloëm). These cells become gradually transformed into xylem elements or phloëm elements, according to their position. The vessels and cells that are brought into existence

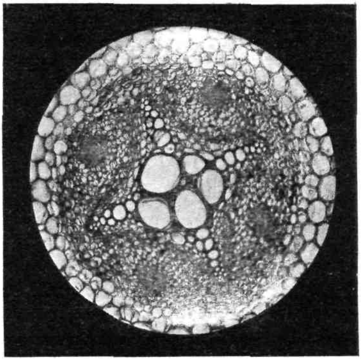


FIG. 53. Transverse section of the root of *Cicer arietinum*, a stage later than in fig. 52. × 400.

by the cambium ring must be differentiated from the vessels in existence prior to the formation of the cambium ring. All the tissues derived from the original meristem tissue of the growing points are called *primary*, and so the xylem and the phloëm formed in the root before the establishment of the cambium ring are *primary*. The cambium itself is newly produced, by the activity of the mature cells that have become permanent ; and so this is *secondary meristem* and not primary. All the tissues originating from the cambial activity should be called *secondary*. Hence the xylem formed by the cambium is *secondary xylem* or wood, and the phloëm is *secondary phloëm*. The development of

the secondary xylem in the root is from the centre towards the periphery, i.e., *centrifugal*.

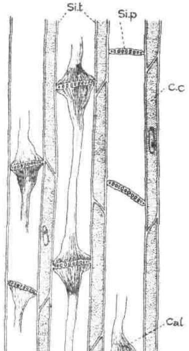


FIG. 54. Sieve tubes in longitudinal section. (*Cucurbita maxima* stem) *Si.t.*, sieve tube; *Si.p.*, sieve plate; *Cal.* callus. *C.C.*, companion cell. × 400.

In older portions of roots the cambium assumes the form of a regular ring and it is a *hollow cylinder* enclosing a mass of xylem both primary and secondary. The phloëm lies outside the cambium ring. It is surrounded by the cortex which may be decaying. *Very soon the cortex* wears out and its place is taken by layers of special cells called cork cells derived from a cork cambium arising from the pericycle.

From what has been said above, it is obvious that a transverse section of an old root should differ from that of a young root very much in its structure. The cortex with its piliferous layer sloughs off in the older roots, and the function of protection is then assumed by the cork layers formed by the cork cambium, arising from the pericycle. The secondary phloëm will be in the form of a ring,

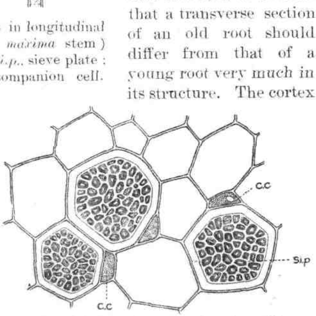


FIG. 55. Sieve tube, transverse section. (*Cucurbita maxima* stem.) C.C., companion cell; *Si.p.*, sieve plate. × 500.

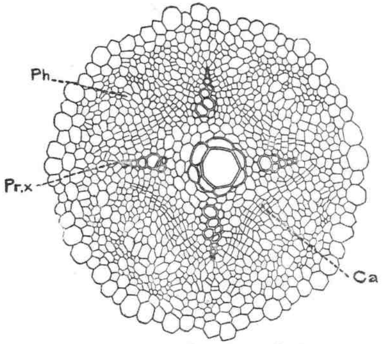


FIG. 56. Transverse section of the root of *Benincasa cerifera*. *Ca*, cambium ; *Pr. x*, protoxylem ; *Ph*. phloëm. × 400.

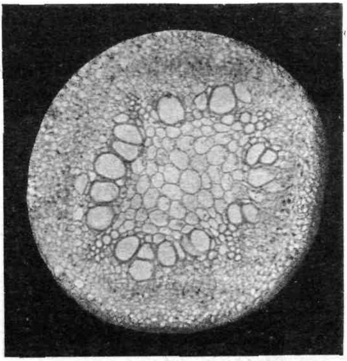


FIG. 57. Transverse section of the root of *Arachis hypogæa* Note the four groups of protoxylem, the four groups of secondary xylem and the cambium. × 400,

although often interrupted by continuous layers of uniform cells called *medullary rays*. The masses of primary phloëm generally get pressed out of shape.

In all essential respects, the roots of dicotyledonous plants resemble the Cicer root so far as structure is concerned. The roots of *Sesbania grandiflora*, *Arachis hypogæa*, *Albizzia Lebbek* and *Benincasa cerifera* are similar to the Cicer root in having four protoxylem groups.

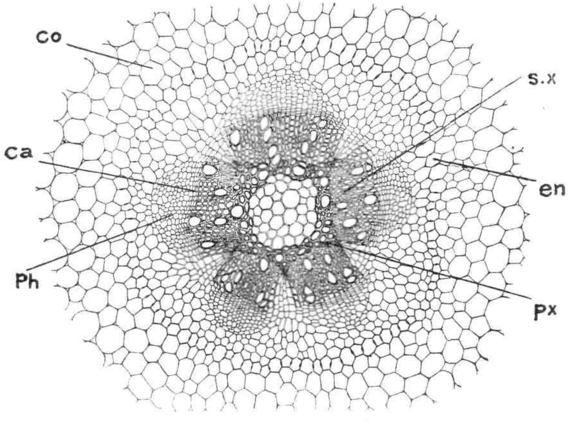


FIG. 58. Transverse section of the root of Castor to show the protoxylem and secondary xylem. *Ca.*, Cambium; *Co.* cortex; *en*, endodermis; *Ph.* phloëm; *Px.* primary xylem; *s.x*, secondary xylem. × 400

However, in the matter of protoxylem groups, dicotyledonous roots vary. Instead of four groups, there may be two, three, six or more. But the number of xylem groups is never very large. The root of *Cucurbita maxima* and the aerial root of the Banyan have six protoxylem groups; in the root of the Radish and Mustard plants we find only two of

these. In the root of the Castor plant there are four, five or six protoxylem groups.

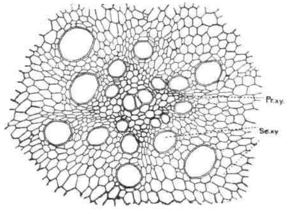


FIG. 59. Transverse section of an old root of *Albizzia Lebbek*. *Pr. xy*, primary xylem : *Se. xy*, secondary xylem. × 100.

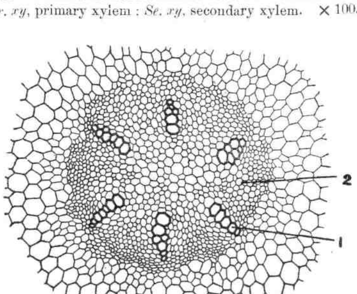


FIG. 60. Transverse section of a very young root of a Cucurbita. 1. protoxylem : 2. protophloëm. × 400.

After the formation of the cambium ring the secondary wood is formed, and after a time both become quite continuous ; so that in an old root the protoxylem (i.e., the primary xylem) cannot be made out except in the earlier stages or in exceptional cases.

Structure of monocotyledonous roots.—Monocotyledonous roots do not differ from the dicotyledonous roots, so far as the

structure of the growing point is concerned. But in the absorbing and the conducting regions, there are some differences in structure. As an example of a monocotyledonous root we may examine the root of *Colocasia Antiquorum*. If we examine a transverse section of this root we find the stele and the cortex very well differentiated, as the endodermis is very distinct. Within the stele there are a number (varying from nine to eleven) of protoxylem groups alternating with as many phloëm masses. The pericycle is also very clearly seen. The cells of the endodermis have their lateral walls (and sometimes even their inner wall) thickened. All monocotyledonous roots have more or less the same structure.

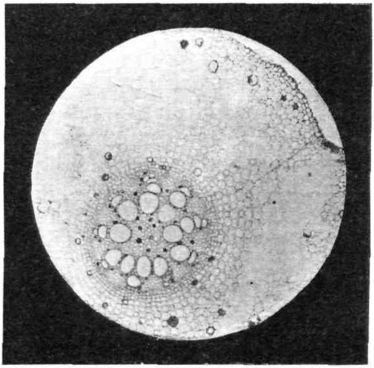


FIG. 61. Transverse section of the root of Colocasia showing the stele and the cortex. Note the nine protoxylem groups. × 100.

Within the stele, only the xylem and the phloëm groups are formed, and no cambium arises, as in the case of the dicotyledonous root. The development of protoxylem is centripetal. The cortex persists in the case of the monocotyledonous type of root, and some of the peripheral layers may also become thickened. This part is termed

exodermis, and it may consist of only a single layer of cells, as in the root of Paddy or, it may have more than one, as in the case of the Cholam root.

As further examples of the monocotyledonous roots we may examine those of Onion, *Andropogon Sorghum* and *Musa paradisiaca*.

In the Musa root the endodermis is a very striking layer, on account of the great thickening of the inner wall of its

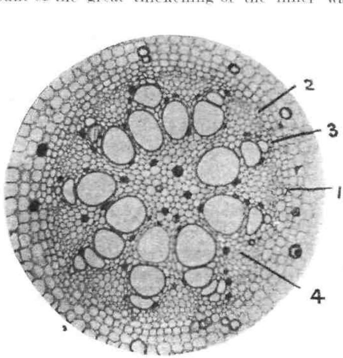


FIG. 62. Transverse section of Colocasia root showing the stele and the endodermis. 1, endodermis: 2, pericycle: 3, protoxylem; 4, phloëm. × 400.

cells. Close to this is seen the pericycle, and the stele is somewhat different in structure from that in the Colocasia root. There are more than thirty groups of protoxylem alternating with as many phloëm groups. The central portion of the stele is occupied by numerous xylem vessels, and there are also phloëm groups irregularly disposed amidst the xylem. The cortex presents no special features, except the very regular arrangement of the cells with uniform intercellular spaces. Another marked feature is the lignification of the walls of all the cells within the stele except

the elements of the phloëm. The exodermis is not so well developed in this root.

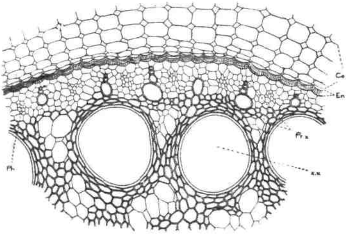


FIG. 63. Transverse section of Musa root showing a portion of the peripheral part of the stele. *Co*, cortex ; *En*, endodermis ; *Pr.x*, primary xylem ; *x.v*, xylem vessel ; *Ph*, phloëm. × 300.

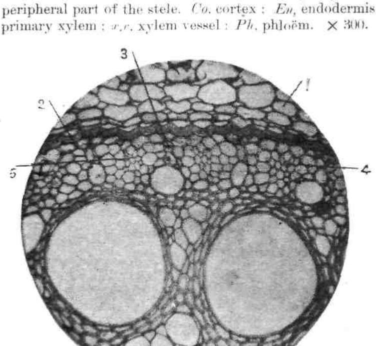


FIG. 63-A. Transverse section of Musa root showing a portion of the peripheral part of the stele. 1, cortex ; 2, endodermis ; 3, pericycle ; 4, phloëm ; 5, xylem. × 500.

The root of the Onion plant presents a much simpler structure. The cortex is generally very broad and the stele

is comparatively very small. Within the stele there are only five to seven protoxylem groups. The endodermis is well seen on account of the thickening of the lateral and the inner walls of its cells. Below this layer is seen another layer, which is the pericycle.

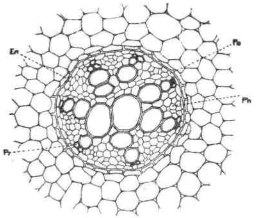


FIG. 64. Transverse section of a root of the Onion plant. *En*, endodermis : *Pe*, pericycle : *Px*, protoxylem : *Ph*, phloëm. × 200.

The root of the Cholam plant though of the monocotyledonous type differs from the Colocasia and Musa roots in

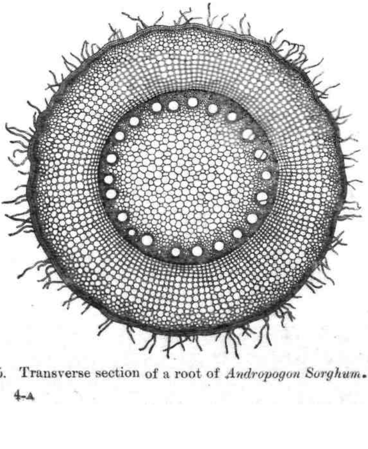


FIG. 65. Transverse section of a root of *Andropogon Sorghum*. × 80.

certain respects. Below the piliferous layer we see in this root a few layers of cells with very thick walls, and this is the *exodermis*. (See fig. 66.) In roots that are aerial the exodermis is very well developed, and the reason for this will become obvious after the study of the structure of the stem. The endodermis is similar to that of the Musa root. There are very many protoxylem groups, the number being sometimes over forty. Generally the pith consists of uniform cells. The pericycle is very well defined and lies immediately beneath the endodermis.

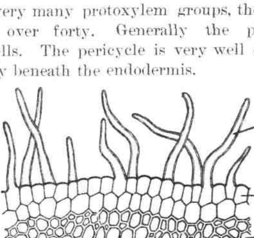


FIG. 66. Transverse view of a portion of the cortex of Cholam root *r.h*, root-hair ; *p.l*, piliferous layer ; *ex*, exodermis ; *co*, cortex. × 400.

In the case of roots the pericycle is a very important layer, because, in both dicotyledons and monocotyledons, the lateral roots arise from it just close to the protoxylem. In dicotyledonous roots, there will be as many longitudinal rows of lateral roots as there are protoxylem groups. For instance, we see in the tap-root of the Dolichos seedling four longitudinal rows of lateral roots, and the protoxylem groups are usually four in this root. The root of the Radish has only two protoxylem groups, and hence we see in it only two longitudinal rows of lateral roots.

Having now learnt the structure of roots, we shall next study how far the structure is adapted for the function the roots have to perform. Considering the absorptive work of the roots, it is obvious that roots should grow in length,

otherwise the roots may not get water to absorb. The part of the root that is best adapted for this growth is certainly the free tip or end of the root. Other parts, the root-hair bearing region and the conducting regions are most unsuited to

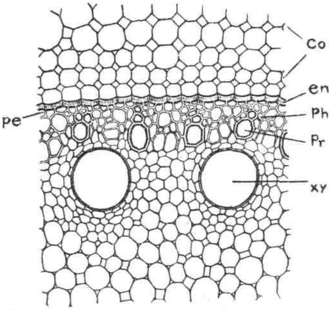


FIG. 67. Transverse view of a portion of the stele of Cholam root. *co*, cortex ; *en*, endodermis ; *ph*, phloëm : *pr*, primary xylem : *xy*, xylem vessel ; *pe*, pericycle. × 400.

bring about the growth in length. Should these parts grow the root-hairs will be damaged very much. The naked tips are very delicate and need protection, and this is afforded by the root-caps. As the root-cap wears out at the outside, fresh layers are added on from the inside. The main work of the root-tip is to produce more cells and thus bring about elongation. There are really two portions in the root-tip, the extreme end or the formative region where the cells are always actively dividing and the elongating region in which the cells become gradually elongated. Root-hairs do not appear in these two regions. If they appear it is a sure indication that growth in length has practically ceased. As already pointed out, if the root-hairs were to appear in the part undergoing elongation they are sure to be crushed and their efficiency would be impaired. The second region of the root is the absorbing region. Here the root-hairs are well developed from the outermost layer of the cortex.

The cells of the cortex, lying below the piliferous layer become larger, and this is what is best for the storage of water. As the absorption increases, the pressure in the cells of the cortex, will also increase. But this increase of pressure is not allowed to go on indefinitely. The conducting tissue draws away water from the cortex and this leads to the diminution of pressure. As root-hairs are developed all round the root, water must of necessity be stored in the cortex. Simultaneously with the development of root-hairs outside, vessels make their appearance in the stele. The xylem tissue (or the vessels) in the stele conducts the water very quickly and thus the pressure in the cortex is very soon lessened.

The life of the root-hairs is generally very short. They are active from a few days to two or three weeks. We already know that these are the organs directly concerned in the absorption of water. The very small quantity of water existing in the form of films around the soil particles find their way into the interior of the root-hairs. The protoplasm within the root-hair seems to secrete certain substances that have a great affinity for water, and so the water gets into the root-hair. The root-hairs tend to increase the surface for absorption very considerably.

The older portions of the root are purely conducting regions. The root-hairs are in such parts decayed and the cells of the cortex become dead. In the dicotyledonous roots the cortex, as has already been said, sloughs off and the necessary protection is given by the cork layers derived from the pericycle. In monocotyledonous roots on the other hand, the cortex persists, though the cells cease to be living. The cortex is needed to afford protection to the structures inside.

The root of a large tree must be extensive and capable of increasing in thickness. A large tree possesses a very stout trunk which may bear several very stout branches ; and then the trunk needs propping up on all sides. Many of the roots at the base of the trunk become very much developed and look like so many buttresses to support the trunk. Often trees happen to grow in odd out-of-the-way places and even then the root-system adapts itself very well. For instance, a tree whose photograph is reproduced in fig. 68 was growing

on a fort wall and the roots had to adapt themselves to their new situation and they have done it admirably, as may be seen in the figure.

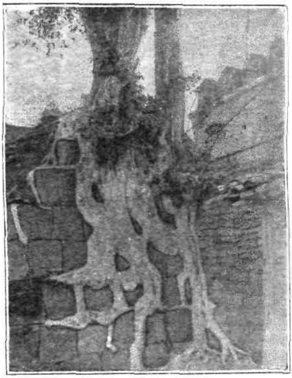


FIG. 68. A Peepul tree with its roots on the face of a fort wall.

So far we have been dealing only with normal roots of land plants. And the functions of these are only fixation and absorption of water. Roots have sometimes to perform other duties besides these. In the case of plants such as Sweet Potato, Radish, Carrot and Turnips the roots are at first normal and they do the usual duty when they are young.

FIG. 69. Radish.

But, as soon as they grow bigger, the roots begin to swell and increase in size. This is because the roots become the reservoirs for the storage of reserve material.

All normal roots are underground. There are, however, many plants in which they are not underground. For instance, in Pandanus, Banyan and Cholam plants there are roots that remain in the air for a long time, although they also penetrate into the soil afterwards. Such roots prop up the plants after entering the ground. When once they get into the soil, these roots also behave like ordinary roots.

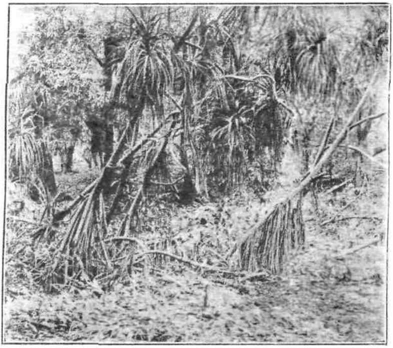


FIG. 70 The aerial roots of Pandanus.

The Banyan tree is an interesting one in many ways. Besides having the well known aerial roots, it is sometimes

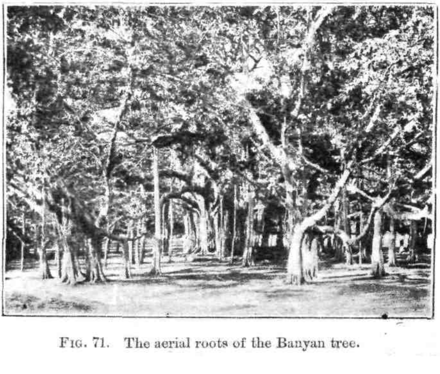


FIG. 71. The aerial roots of the Banyan tree.

epiphytic in the seedling stage, especially when the seeds fall on other trees. We often see Banyan seedlings on palmyra trunks. They grow in this position, and the roots encircling the stem and then gradually going downward get into the soil.

In some climbers such as the Pepper and *Pothos scandens* we find aerial roots at the nodes and these help the stem to cling on to the bark of the trees on which these grow. (See fig. 73).

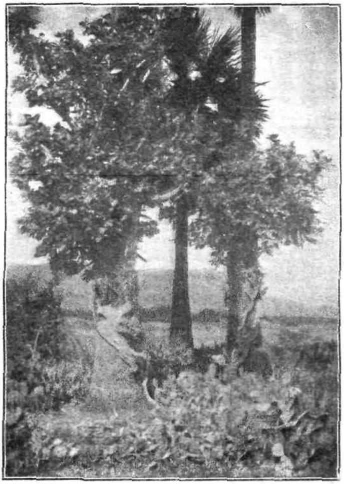


FIG. 72. A Banyan tree growing on the trunk of a Palmyra.

We have a large number of plants mostly of the family Orchideæ whose roots remain in the air without ever getting into the soil. All such plants are called *epiphytes*. The roots of epiphytes are specially adapted to obtain water and salts mostly from the atmosphere. The aerial roots of these plants have a few of the peripheral layers of the cortex modified

into a kind of spongy tissue, called the *velamen*, so as to enable the root to get water from the air. The orchid *Vanda Roxburghii* (see fig. 74) is a good example of an epiphyte.

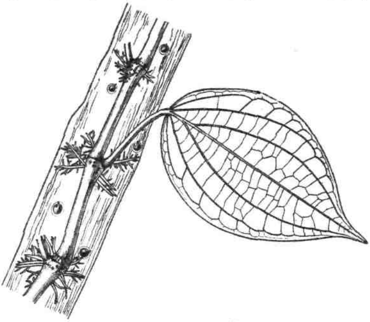


FIG. 73. Aerial roots of Pepper vine.

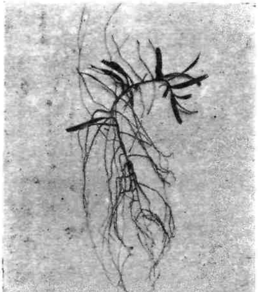


FIG. 74. *Vanda Roxburghii* (an epiphytic orchid).

The root-systems of the family Leguminosæ are specially interesting. In all plants of this order the roots develop

special bodies varying in shape and size, and these are called *bacterial nodules*. They are called so, because they are brought into existence by bacteria. These nodules have the power of using the nitrogen of the atmosphere and thus lead to an increase of nitrogen in the soil.

FIG. 75. The breathing roots or pneumatophores of Avicennia.

Plants growing in salt marshes have their roots in the mire. So the root-system cannot obtain sufficient quantities of oxygen for respiration unless there is some special adaptation. The roots of these plants send up into the air special roots possessing a hole at the top to allow air to get into the root-

system. These are called breathing roots or *pneumatophores* or *pneumathodes*.

Lastly we should mention the modified roots of parasitic plants, such as the Loranthus and the Viscums. These parasitic plants grow on the branches of other plants, sending their modified roots (*haustoria*) into the interior of the branches of their host plants. Complete fusion takes place between the xylem of the haustoria and that of the host plant. Some parasitic plants attach themselves to the roots of their host plants, instead of the stem or branches. *Striga lutea* and the Sandal wood tree are ,well known parasites. Both these plants do not look like parasites, because the haustoria are attached to the roots of the host plants that are underground.

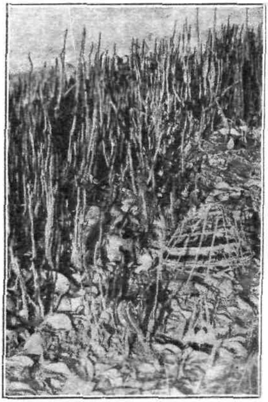


FIG. 76. The breathing roots of Avicennia.

A very remarkable root parasite thrives in the island of Sumatra. It consists of only a gigantic flower attached to the root of vines. When in full bloom the flower is said to be about a metre in diameter and many pounds in weight.

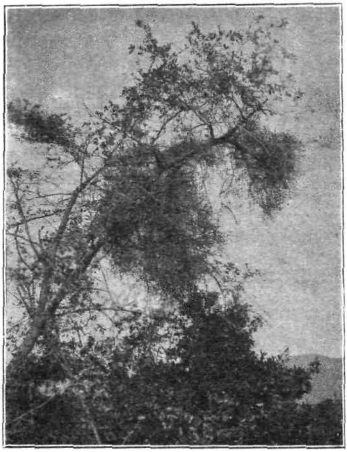


FIG. 77. Viscum on the branches of Hardwickia.

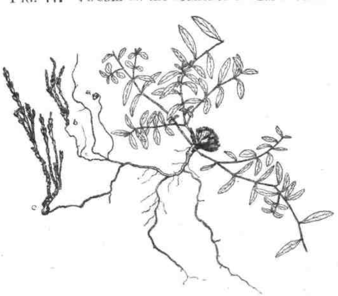


FIG. 78. Striga on the roots of *Lepidagathis cristata*. *a*, *b* and *c* are the parasitic Striga plants.

FIG. 79. Loranthus on a branch of *Albizzia amara*

CHAPTER V.

THE SHOOT.

FROM the study of seeds and seedlings we have learnt that the embryo plant consists of a primary axis and cotyledons and that the former grows into a seedling. The primary axis invariably emerges out of the soil, at first as a loop, and then erecting itself grows and produces green leaves. Further the plumule, which in the seedling develops into an axis bearing green leaves, will always go straight up seeking air and light. We speak of the aerial portion of a plant as the *shoot*, and in the case of a seedling the shoot consists of only a few leaves and an axis.

By closely looking at the branches and twigs of any common tree we find that these grow out into the air so as to *get plenty of air and sufficient light. The parts of the shoot* system need air and light to discharge their functions and, *therefore, stems and branches grow towards the light.* All green plants possess the power of adjusting their branches to light. *That the shoot of a young plant has a perception* of the direction may easily be demonstrated. If a flower-pot in which seedlings are growing be placed on its side, so as to have the axis of the seedling parallel to the ground, the shoot will begin to curve upward somewhere near the young tip, and in about an hour or two there will be a distinct curvature and the shoot will assume an erect posture by bending at right angles to the ground. The upright position of the stem is after all the most advantageous one for the plant and so the shoots of all green plants assume this position.

The plumule, which develops into the primary shoot in a seedling, is only a bud occupying the free end of the primary axis. We cannot make out its structure at the earlier stages of its development. But, as soon as it begins to grow in length, it becomes apparent that it is only a short stem hidden by a number of enfolding leaves. Gradually the stem

elongates, the nodes become separated from one another and the leaves also, which are crowded upon it at first, become separated. The leaves develop in acropetal succession.

All plants begin their lives with a single stem and afterwards branches grow out from the axils of leaves. Branches behave like the main stem, in the matter of producing branches. So the shoot-system of a plant or a tree is merely a repetition of the stem from which it arises, and it consists of a number of branches, and every one of them consists of an axis, and the leaves and flowers borne by it. The axis is divisible into nodes and internodes, and it terminates in a bud. All growing normal branches have buds, at their free ends. If the apex of a branch ceases to be active, on account of unfavourable conditions, the terminal bud assumes the form of a resting bud and becomes prominent as in Mango, Cinnamomum, Rhododendron and Mahogany.

In addition to the terminal bud, every branch possesses also axillary buds. In a branch all the leaves have axillary buds, and so there will be as many buds on it as there are leaves. Generally these buds do not arise from the axils of cotyledons, but even this is not without an exception. Buds develop from the axils of the cotyledons in the Ground-nut plant *(Arachis hypogæa)*.

When the plumule is injured while still very young, axillary buds sometimes grow out from the axils of the cotyledons as in the case of the Mango and a few leguminous seeds *(Canavalia ensiformis)*.

The primary shoot, in virtue of its having axillary buds, is capable of producing a large number of twigs. So the young branches increase rapidly causing the formation of a large shoot-system, which constitutes the body of a shrub or the head of a tree. The branching and the general shape of the head of a tree is sometimes quite characteristic of the species as in *Odina Wodier*, *Ailanthus excelsa*, *Acacia planifrons* and the Rain Tree.

The bud and the branch.—A bud, terminal or axillary, is only an undeveloped branch. It consists of a free end which is a mass of meristem cells, covered by the very tender young leaves in the course of development. The leaves arising as protuberances from the surface of the free end, which is

called the growing point, grow earlier and faster than the axis so that it may have protection. (See fig. 80). A branch may have a large number of buds, but only those that have the best chance grow. There are generally more buds than there is space for, and so there will be a struggle for existence amongst them. Those buds that have more sunlight and room than the others grow best. The terminal bud and the axillary buds towards the top of the branch grow better and become larger because they get more sunlight, air and room.

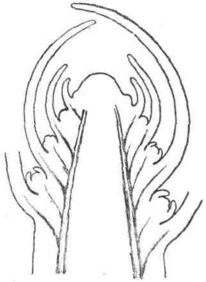


FIG. 80. The growing point of a stem. × 100.

Twigs in some cases tell the story of their own growth. By an examination of a twig it is possible, in many cases, to

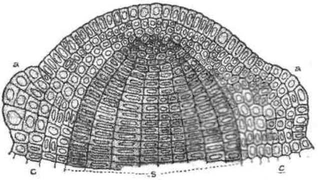


FIG. 81. The growing point of a stem. (After Sachs.) × 400.

determine exactly its age. It is especially easy in twigs that possess scaly leaves covering the bud, to determine their age. In such twigs, the scars of the scaly leaves are succeeded by those of the foliage leaves. The twigs of Mango and Mahogany are good examples to illustrate this point.

The primary shoot of a plant is at first single. It may continue to grow and produce branches, or it may grow as a

simple straight stem without any branches and remain so throughout its life. In the case of several palms, such as the Coconut, Areca-nut, Palmyra and other palms the stem is single, and it bears no axillary buds. When a stem goes on elongating by the growth of its terminal bud for a long time it is said to be a branch with indefinite growth. Sooner or later, branches grow out from the lower axils also and these may be numerous and all smaller than the main stem. This mode of branching of the stem is called *racemose*, and the branch whose elongation is due to the growth of the terminal bud is said to be a *monopodial* branch.

The terminal bud, instead of continuing the growth of the axis, very often ends in spines or flowers and so the main axis ceases to elongate. For instance, in the plant *Carissa Canardas*, the growing point ends in two spines and

FIG. 82. Twig of Mango. *a*, terminal scaly bud. *b, c, d*, scale scars.

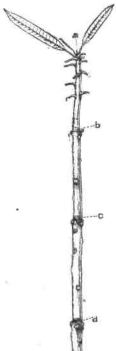


FIG. 83. Twig of Mahogany. *a*, scales ; *b, c, d*, scale scars.

the two axillary buds in the axils of the leaves immediately

below the spines grow into branches. These also, after producing two or three pairs of leaves, end in spines and behave in the same manner.

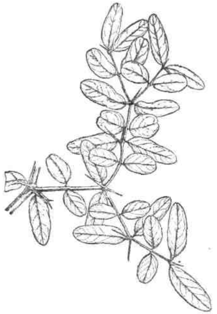


FIG. 84. A branch of *Carissa Carandas*.

In the Cotton plant the flowers are opposite the leaves. This is so as the main axis ends in a flower and there is no growing point to continue the growth of the same axis. The axillary bud lying immediately below the terminal growing point grows and continues the axis, by pushing aside the flower. So the internodes of the flower bearing branch in the Cotton plant are not all derived from the same growing point. Such branches as these are called *sympodial* branches and the branching is *cymose*.

Branches of *Vitis quadrangularis* bearing *tendrils* (climbing organs) may be taken as an example of a sympodial stem. Obtain some branches of this plant and choose two, one having tendrils from every node and another having them only at some of the nodes. In a branch having tendrils from every node an internode springs from between a leaf and a tendril. On the other hand in a branch without tendrils at the nodes, we find a leaf, an axillary bud and the main axis, at every node. The axillary bud is small and it lies between the leaf and the main axis. By comparing the tendril bearing node with one

FIG. 85. A flower bearing branch of the cotton plant. A, B, C, internodes; *a*, *b*, *c*, flowers; *a′*, *b′*, *c′*, leaves.

having no tendrils, it is possible to make out the nature of the tendril. The tendril is found opposite the leaf and the internode lies between it and the leaf. Judging from the relative position of parts, the tendril is in the position of the main axis, and the internode is found in the place of the axillary bud. In the Vitis branch figured here the internode "B" arising from the axil of the first leaf is evidently derived from the axillary bud of that leaf. The tendril found opposite to this leaf is really the main axis which has given rise to the axillary bud, now grown into an internode "B," the second leaf and the second tendril. As the axillary bud has grown more vigorously than the main axis (now a tendril) it has pushed it aside. The internode "C," the third tendril and the third leaf are derived from the axillary bud of the second leaf. Similarly the internodes "D" and "E" are derived from two different axillary buds. The axis of the branch is straight and consists of the several internodes "A," "B," "C" and "D." Now it is obvious that all these internodes though continuous are not produced by the same growing point, and that each one is developed from a separate growing point. The internode "A" has an origin different from that of "B" or "C" or "D." The whole branch "A" to "D" though appearing as one continuous piece of axis really consists of four separate axes derived from different growing points.

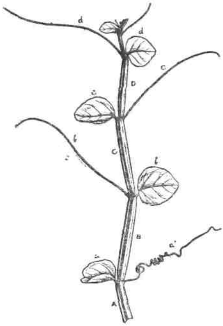


FIG. 86. A tendril bearing branch of *Vitis quadrangularis*. A, B, C, D, internodes: *a*, *b*, *c*, *d*, leaves; *a′*, *b′*, *c′*, *d′*, tendrils.

Modified stems.—Stems generally grow erect, but they do not always do so. Many plants have very weak stems and they cannot be expected to maintain an erect posture

without supports. Such plants if not supported must grow along the surface of the soil. The branches of the plants *Hydrocotyle asiatica*, *Ipomœa reniformis* and *Lippia nodiflora* creep along the ground; and as they do so, from their nodes adventitious roots arise by which they get fixed to the soil. The axillary buds at the nodes grow erect producing leaves and branches. These are capable of becoming independent plants, if they get severed. Such branches as these are called *runners* or *stolons*.

FIG. 87. Stolons of *Hydrocotyle asiatica*.

Certain plants have a tendency, because of their weak stems, to twine themselves round a support. Several species of Ipomœa, *Dolichos Lablab*, *Clitoria Ternatea* and *Teramnus labialis* are such plants. All these plants are called *twiners*, because their stems twine round a support. The support may be the stalks and branches of plants growing near. When the stems of climbers become thick and massive, they are called *lianes*. For instance the plant *Combretum ovalifolium* is such a one.

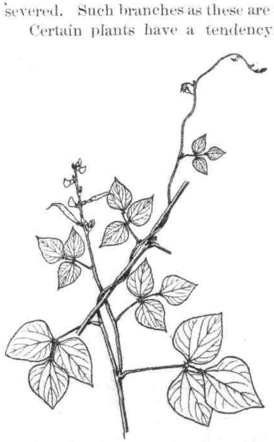


FIG. 88. Twining stem of *Dolichos Lablab*.

Again there are certain plants like the Gourds and the Cucumbers that climb by means of special structures called *tendrils*. The nature of the tendril varies with the kind of plant. It is a branch in Passiflora, because it springs from the axil of a leaf; in the Pea plant the tendril is in the position of a leaflet: it may arise from the apex of a leaf, as in *Gloriosa superba*; the flower-stalk sometimes develops into a tendril, as in Cardiospermum and Antigonon; in some species of Cucurbita it is a leaf.

FIG. 89. Old twining stems of *Combretum ovalifolium*.

The axillary branches sometimes remain short and become pointed at the tips instead of developing into leafy branches; such branches are called *spines* or *thorns*. Very often these spines, or arrested branches bear leaves and may also develop into leafy branches under exceptionally favourable conditions, and especially under cultivation.

Underground stems.—There are many plants in which the main portion of the leaf bearing axis generally remains underground and only the leaves and the tip of the axis of the branches come out of the soil. In such cases the stem becomes thickened, grows horizontally either at the surface

of the soil or below it, giving off leaves above and roots below. The underground portions of the plants *Canna indica*, Ginger, Curcuma and *Panicum repens* are stems of this kind and they are called *rhizomes*.

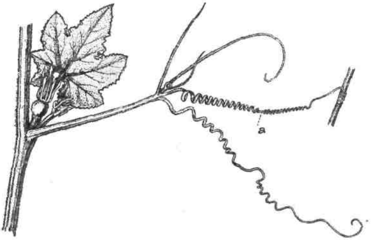


FIG. 90. Tendrils of Cucurbita.

In some rhizomes it is possible to make out the nodes, internodes and the axillary buds.

Sometimes we meet with plants in which a few branches remain underground and these instead of elongating swell and become thick on account of the storage of starch. In such branches leaves do not develop but axillary buds are always present. Underground branches of this nature are known as *tubers*. The Potato is a good example of a tuber. In the Potato plant, in addition to the tubers, there are also ordinary branches with leaves.

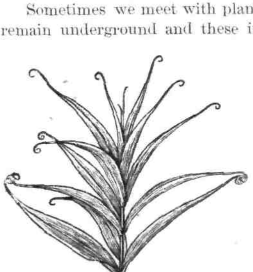


FIG. 91. Tendril bearing leaves of *Gloriosa superba*.

In tubers and rhizomes the axis is well developed, but the leaves are either absent or, they are reduced to scale-leaves.

FIG. 92. Tendrils of Cardiospermum.

There are some plants in which the axis remains small without development, but the leaves grow and become fleshy so as to serve as reservoirs for reserve food. This is exactly what happens in the case of the Onion plant. If we cut an Onion longitudinally, we find a disc-like structure bearing roots below and a number of sheathing fleshy scale leaves and buds above. This disc is the stem or the axis very much condensed, and the whole structure is called the *bulb*. As further examples we may mention those of Crinum, Scilla, Urginea and Polianthes.

The inner leaves of a bulb are either fleshy scales as in Onion or they are the enlarged sheathing leaf bases of ordinary leaves as in Crinum. The bulb in Polianthes is generally like that of Crinum or Onion, but the axis becomes a large mass instead of remaining small and then the scale-leaves are very few. Externally it is like a bulb and so such ones are sometimes called "*solid bulbs*." This is really an intermediate form of stem leading to what is usually described as a *corm*.

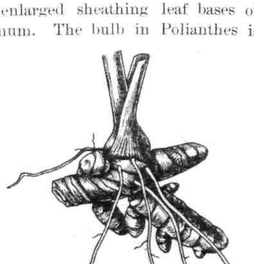


FIG. 93. Rhizome of Curcuma.

There are a few plants in which the axis lying at or below the level of the soil, swells out into a spherical

shape on account of the accumulation of food material. The leaves either become reduced or they are entirely absent. The underground massive part of the plant

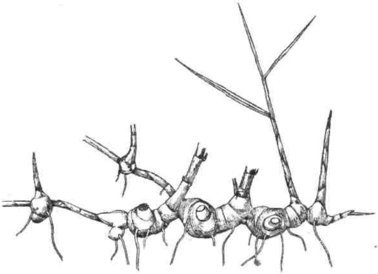


FIG. 94. Rhizome of *Panicum repens*.

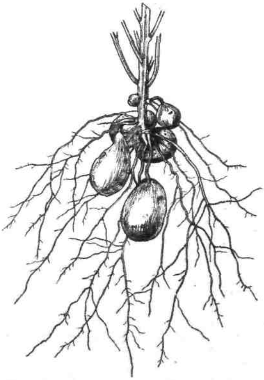


FIG. 95. Tubers of the Potato plant.

Amorphophallus, or Synantherias is the main stem modified and this is a good example of a naked corm. Though

this is essentially like a tuber, it differs from it in being a main stem instead of a branch. Hence it is called a *corm*. The so-called "solid bulbs" are corms covered by scale-leaves.

The corm of Amorphophallus bears a large bud at its depressed apex. The apical bud pushes out the leaves one at a time. In addition to this bud a number of smaller ones are found scattered all over the surface of the corm and also in the depressed part. Some of these may develop into

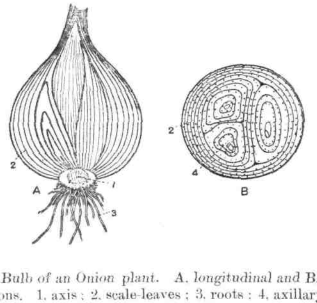


FIG. 96. *Bulb of an Onion plant. A. longitudinal and B. transverse* sections. 1. axis; 2. scale-leaves; 3. roots; 4. axillary buds.

daughter-corms. Sometimes we find corms of different periods of growth remaining attached to one another. For instance the corms in a wild species, *Synantherias sylvatica*, consist usually of two bodies as shown in fig. 97. The upper one is the corm of the plant that has resulted during the period of growth in 1914, and the lower one is of the year 1913. From the corms sometimes buds grow out and become elongated somewhat like the rhizome. The underground structure found in *Colocasia Antiquorum*, in continuation with the

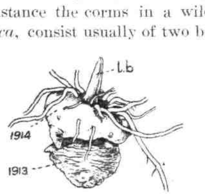


FIG. 97. Corm of *Synantherias sylvatica*, Schott. *l.b.*, leaf bud.

developing bud, is a corm; and this usually bears branches somewhat elongated and resembling a rhizome.

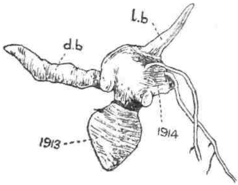


FIG. 98. Corm of *Synantherias sylvatica*. *l.b.*, leaf bud; *d.b.*, daughter bud.

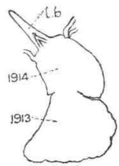


FIG. 99. Corm of *Synantherias sylvatica* cut longitudinally. *l.b.*, leaf bud.

The internal structure of the stem.—The structure of the stem varies according to the species of the plant and the stage of development in the same plant. In plants having a short duration of life, as in the case of annuals, the stem is generally soft and herbaceous. In shrubs and trees the stem is herbaceous in the younger parts, and is woody and hard in older portions.

The structure of the growing point of the stem is the same in all plants, so far as the essential points are concerned. It consists of a mass of meristematic cells terminating in a cone and covered by the developing young leaves. Axillary branches also arise very early as protuberances in the axils of leaves near the actual growing point. They remain dormant for a very long time. It is the leaf that grows rapidly one after the other while the axis does so very slowly. In consequence of this difference in growth between the axis and its appendages, the young leaves developing near the growing point cover and protect it.

To learn the internal structure of the stem it is necessary to select the stems of a few plants as types and study them. We may begin the study with the stem of a Sunflower plant. If we examine a transverse section of this stem taken a little below the growing point we find in the central part a mass

of thin-walled cells, and this portion of the stem is called the *pith* or *medulla*. All round the pith which occupies rather a large part of the area in the transverse section there are *groups of cells with thick cell-walls arranged in the form of* a ring. Between these groups of thick-walled cells there are bands of parenchymatous cells which are, though smaller, similar to those of the pith.

These isolated groups standing out prominently, by reason of their thickened cell-walls, are the cut ends of the vascular bundles that run longitudinally in the stem, and they increase continually in thickness, especially in the case of the dicotyledonous stems. The mass of wood found in the stems *of timber trees of several year's growth is nothing more than* a mass of vascular bundles packed together closely. The bands of parenchymatous cells seen in the transverse section between the vascular bundles, and running from the cortex

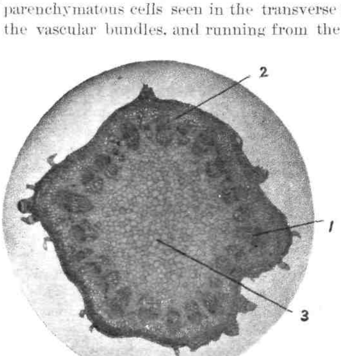


FIG. 100 Transverse section of a Sunflower stem.
1, vascular bundles ; 2, cortex ; 3, medulla or pith. × 200.

to the medulla are called *medullary rays*. At first when the vascular bundles are isolated these medullary rays are broad. Later on new vascular bundles arise in these rays making the bundles continuous.

The structure of a single vascular bundle of the Sunflower stem is shown in fig. 102. The larger cavities with thick walls are the vessels. Amidst the vessels, there are small cells with thick lignified walls. They are ordinary

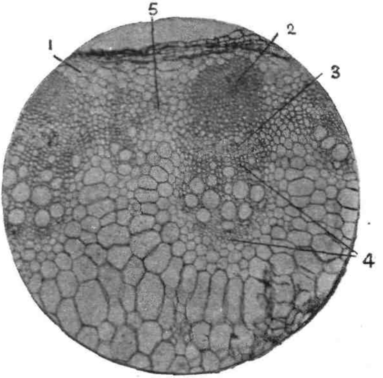


FIG. 101. Transverse section of a portion of the Sunflower stem. 1, cortex ; 2, fibre bundle ; 3, phloëm ; 4, xylem ; 5, cambium. × 400.

parenchymatous cells whose walls are lignified and fibres. The lignified vessels, wood parenchyma and fibres form a compact group near the pith, and it is the xylem of the vascular bundle. Besides these thick-walled elements, forming the xylem, there are other groups of cells with thin walls which are also the constituents of the bundle. We have, as a matter of fact, three distinct parts in a vascular bundle, viz., the xylem, the cambium and the phloëm.

The xylem consists of thick-walled vessels and cells and fibres. It lies close to the pith. Vessels lying close to the pith are the oldest ones and those on the opposite side far away from the pith are the youngest.

Next to the xylem towards the periphery of the stem we see several layers of thin-walled cells. Of these those that

are rectangular and regular remain close to the xylem, and this is the cambium region. All the cells of this region are not meristematic: only one layer is so, and it is the cambium proper. In the vascular bundle the most delicate part is the cambium.

The cambiums of the bundles found in the young stem *do not touch each other laterally*, because medullary rays run between the bundles. Later on these areas of *cambium* become united into a continuous ring. The cells of the medullary ray lying between the cambium of the bundles become active, change into meristem and connect the adjoining pieces of the cambium.

The tissues lying outside the cambium consist of thin-walled cells grouped together with a mass of very thick-walled cells, outside, towards the cortex. The thin-walled cells constitute the phloëm, and the mass of uniform cells with thick walls is a group of fibres. The phloëm is *really* made up of sieve tubes and parenchymatous cells and it is protected by a mass of fibres lying outside, towards the cortex. *In the Sunflower* stem we find fibres associated with the vascular bundles, and so the bundle is sometimes called a *fibro vascular bundle*. The fibre bundle is not a part of the vascular bundle.

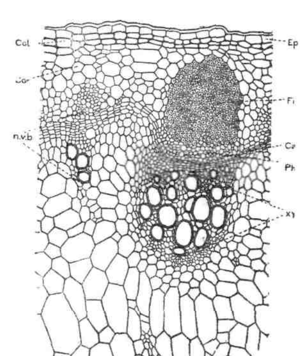


FIG. 102. Transverse section of a single vascular bundle of the Sunflower stem. *Ep*, epidermis; *Col*, collenchyma; *Fi*, fibre bundle; *Ph*, phloëm; *Ca*, cambium; *Xy*, xylem; n.v.b., new vascular bundle. × 500.

To understand the structure of the elements of the various parts of a vascular bundle, it is necessary to examine a median longitudinal section. Such a section is represented in fig. 105. The pith and the cortex consist of thin-walled parenchyma. The outermost layer of the stem consists of thin-walled flattened cells : this is the epidermis. The outer

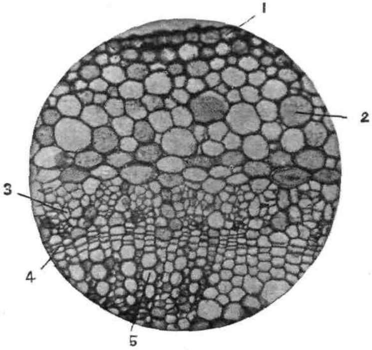


FIG. 103. Transverse section of a very young stem of *Hibiscus cannabinus*. 1, epidermis ; 2, cortex ; 3, phloëm ; 4, cambium ; 5, xylem. × 200.

free wall of the epidermal cells are thickened, and the thickened part is known as the cuticle. Within the cortex the various elements of the vascular bundle and fibre are seen. The innermost layer of the cortex is in contact with the fibre bundle. The fibres have very thick walls and they are also pitted though slightly. Next to the fibres lie the sieve tubes and ordinary parenchymatous cells. The sieve tubes are all small and so they can be seen well only under high powers of the microscope. The phloëm is succeeded by the cambium layer and after this are seen the xylem elements, vessels, fibres and wood parenchyma cells. The vessels

towards the cambium are all pitted and near the pith lie the annular and spiral vessels.

We have already spoken about the importance of the cambium layer. It is really a single layer of cells and these cells are always undergoing division giving rise to new cells both towards the phloëm and the xylem. Cells near the xylem become gradually changed into xylem elements (pitted vessels, wood parenchyma and fibres), and those next to the phloëm become sieve tubes and parenchymatous cells.

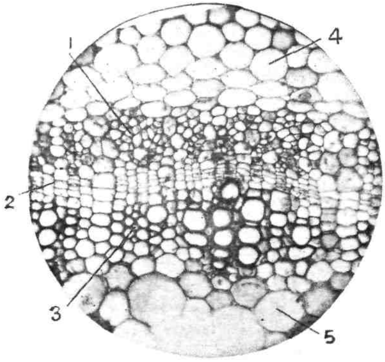


FIG. 104. Transverse section of a portion of a very young stem of *Hibiscus cannabinus*. 1, phloëm; 2, cambium; 3, xylem; 4, cortex; 5, medulla × 400.

The cambium exists at first as small patches between the xylem and the phloëm of the isolated vascular bundles. The formation of the cambium ring is a gradual process. A little below the growing point the uniform mass of cells become differentiated into a central core in which the cells are elongated in the longitudinal direction and a peripheral portion wherein the cells are not so much elongated. The

central core is called the *stele*. Here and there, within the stele which is uniform in its structure, cells begin to divide rather rapidly, and as a result of this division a continuous ring of small cells is formed. The portion of the stele inside this ring is the medulla or the pith. In this ring which is called the *procambium* isolated strands appear (*procambial strands*). And these strands become changed gradually into vascular bundles, separated by medullary rays. The transformation of the procambial strand into the vascular bundle

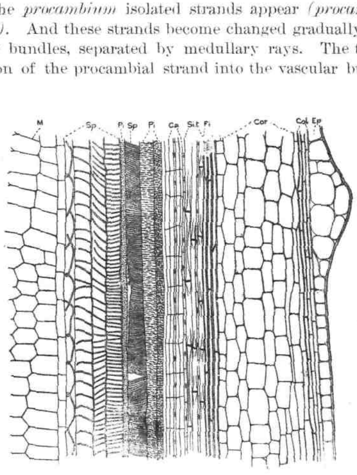


FIG. 105. Longitudinal section of the Sunflower stem. *Ep*, epidermis; *Col*, collenchyma; *Cor*, cortex; *Fi*, fibre; *Si.*, sieve tube; *Ca*, cambium; *Pi*, pitted vessels; *Sp*, spiral vessels; *M*, medulla or pith. × 300.

is a very gradual process. A portion of this strand which is towards the medulla becomes differentiated into xylem, and the part on the side of the cortex develops into phloëm. A small patch forming the middle part of the strand is left unchanged and it retains its meristematic condition. These bits of cambium are called *fascicular cambiums* to distinguish

them from the cambium formed later in the medullary rays, which is called *interfascicular cambium.*

A stem is an elongated structure consisting of many bits superposed one above the other, the limits being the places where the leaves are inserted. Every piece is made up of cells, most of them being parenchymatous. The parenchymatous cells show a great activity at a certain period of their life. All the cells except those of the xylem are full of protoplasm. The vascular bundles run through the mass of parenchyma longitudinally and at every node a few strands of the vascular bundles leave the stem and enter the stalk of the leaf.

The stem is connected with the root and so the vascular strands of the stem and the root are continuous. On the other side the bundles of the leaf are also continuous with those of the stem.

The growing points and the parenchymatous cells must be supplied with food materials, and the assimilated food materials should be transported from the manufacturing cells. For this purpose special passages should exist. Vascular bundles are such special passages. The woody portion of the vascular bundle conducts the raw solution from the root to the manufacturing cells. The sieve tubes carry the organic material which has been built up in these cells to all these places where new cells are to be formed.

The medulla is an important portion only in young stems. In older stems this consists of dead cells filled with air. The function of the pith in young stems is to swell up the axis and accelerate its growth in length. Another function is the storage of reserve substances.

The medullary rays consist of parenchymatous cells, somewhat elongated in the radial direction. In young stems these rays are generally broad and are called *primary medullary rays.* As the stem gets older and older the primary medullary rays get narrower and narrower, because of the formation of new vascular bundles. These rays afford the most convenient passage for the transport of the material in a radial direction. So long as the vascular bundles are isolated, the whole of the medullary ray consists of parenchyma. But as soon as the xylem becomes a continuous ring

that part of the ray which runs through the xylem becomes differentiated. The cells become somewhat elongated in the radial direction and the walls are lignified. In most cases the wood parenchymatous cells of these rays are filled with starch grains. Such medullary rays run right through the xylem or they may run only to a certain distance. The former are called *primary* and the latter *secondary medullary rays*.

We have now studied the structure of the Sunflower stem in a detailed manner, and this may be taken as the type of a herbaceous stem. In this stem there are three distinct parts, the epidermis, the cortex and the stele. The epidermis has a distinct cuticle and also hairs. It is a protective layer. The cortex consists of several layers of parenchymatous cells, with a few resin ducts. Just below the epidermis the cells of the cortex are somewhat thickened, especially at the corners where the cells meet. Cells having this kind of structure form a tissue called *collenchyma*. We shall have to speak about these kinds of tissues again. The innermost layer of the cortex consists of cells containing starch grains occasionally and this layer is called the *endodermis* or the *starch layer*.

Within the stele we find a number of isolated fibro-vascular bundles arranged around a broad core of pith. The bundles have between them the medullary rays. Behind the vascular bundle, and between the endodermis and the phloëm, lies the bundle of fibres. The part of the medullary ray lying between the masses of fibres consists of thin-walled parenchymatous cells. The fibre masses together with the part of the ray between them form a continuous ring, just outside the vascular bundles and inside the endodermis. This part is the outermost part of the stele. These layers constitute what is called the *pericycle*. The vascular bundles arise, not quite outside in the stele, but somewhat inside always leaving one or more layers of cells outside. In other words the endodermis will not be found to be in direct contact with the vascular bundles, but it will be separated from the bundles by the pericycle. At first the vascular bundles possess only fascicular cambium, but very soon interfascicular cambium is produced and the cambium

becomes a continuous ring. In older portions of the stem, the xylem is a continuous hollow cylinder.

As further examples, we will do well to examine the stems of a few more plants. The stem of *Aristolochia* may be studied. In a transverse section of this stem we see clearly the epidermis, the cortex and the stele. Within the stele there are a number (5 to 11) of vascular bundles separated by broad medullary rays. (See fig. 106.) The vascular bundles consist of the xylem, the phloëm and the cambium between them. The endodermis is clearly seen, because the layers of cells inside in contact with it are thick-walled. Between the endodermis and the vascular bundles we find two distinct bands that are continuous. The layers of cells with thick walls are the fibres and instead of being in the form of isolated bundles, they are in the form of a continuous ring. Below the ring of fibres lies a broad band of parenchyma. These layers together constitute the pericycle. The epidermis has a cuticle and the central part of the stele is the pith. In this stem, the interfascicular cambium makes its appearance very slowly and gradually.

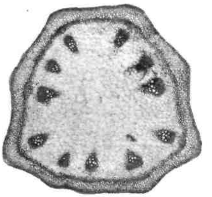


FIG. 106. Fibre bundles (mechanical tissue) in the form of a continuous ring in the transverse section of the stem of Aristolochia as seen under low power.

Woody stem.—As an example of this type we shall choose the stem of *Thespesia populnea*. A transverse section of a year old stem has a well marked pith surrounded by a close hollow cylinder of xylem which has more of wood parenchyma than vessels. Then comes the cambium ring consisting of a few layers of cells that are narrow and quite regular in arrangement. Even in young stems the cambium is more or less a continuous layer. (See figs. 103 and 104.) Outside the cambium there are the phloëm masses arranged so as to form a

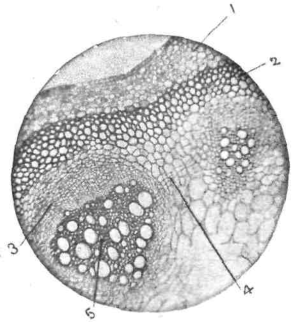


FIG. 107. A portion in the transverse section of the stem of *Aristolochia bracteata*. 1, cortex; 2, pericycle of fibres; 3, phloëm; 4, interfascicular cambium; 5, xylem.

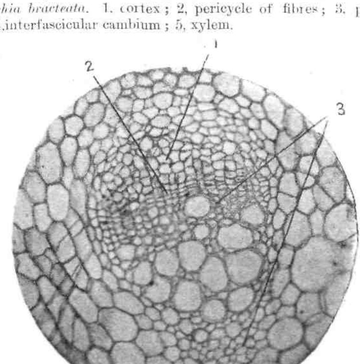


FIG. 107-A. Transverse section of a single vascular bundle in the stem of *Aristolochia bracteata*. 1, phloëm; 2, cambium; 3, xylem. × 400.

ring although interrupted by broad medullary rays. The phloëm consists of alternating layers of soft tissue and groups of fibres. The cells of the medullary ray lying between the phloëm masses are somewhat elongated in the tangential direction. The cortex is not broad and it consists of a few layers

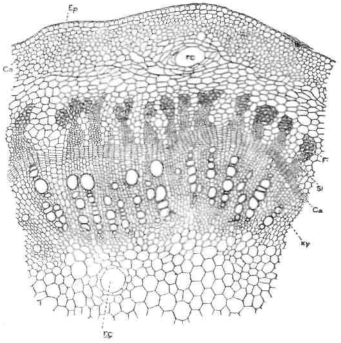


FIG. 108. Transverse section of the stem of *Thespesia populnea*. *Ep*, epidermis ; *Co*, cortex ; *rc*, resin canal ; *fi*, fibre bundle ; *Si*, sieve-tube ; *ca*, cambium ; *xy*, xylem. × 300.

of ordinary parenchymatous cells lying beneath a thin band of collenchyma, which is covered by the epidermis. In very young stems outside the collenchyma there will be only the epidermis. But in the case of the older stems, between the epidermis and the collenchyma, we find a few layers of cells all very regularly arranged. This is *cork tissue*. As the dicotyledonous stem increases in thickness due to the activity of the cambium, the outermost layer or the epidermis should also be expected to keep pace with the growth of the stem. Up to a certain limit the epidermis retains the power of extending its dimensions by cell division, but afterwards it loses this power and may get torn.

Long before the time the rupture is likely to occur, cork layers begin to be formed. A layer of parenchyma cells in

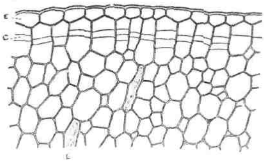


FIG. 109. Formation of cork cells in the cortex of a very young stem of Jatropha. *E*, epidermis ; *C*, cork cambium ; *L*, latex tubes.

the cortex, below the epidermis, becomes meristematic and a cork cambium layer goes on producing cells outside on the side of the epidermis, and they gradually change into cork cells.

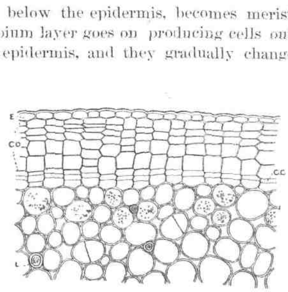


FIG. 110. Formation of cork cells in a stem of Jatropha older than in 109. *E*, epidermis ; *Co.*, cork cells ; *Cc*, cork cambium ; *L*, latex tubes.

In the woody type of stem the amount of xylem is great, as the cambium is always active. As regards the component elements of the xylem the primary xylem consists of chiefly spiral vessels and reticulated vessels, though occasionally annular vessels may also be found. But soon after the establishment of the secondary thickening by the cambium ring, the elements of the secondary xylem will be mainly

pitted vessels. Of course the cementing elements, wood parenchyma and wood fibres, are formed both in the primary and the secondary wood.

Monocotyledonous type of stem.—In the stems of Cholam, Sugarcane, Paddy, Bamboo, Grasses and Palms (all these are monocotyledons) the vascular bundles are found scattered amidst a mass of parenchymatous cells. Each vascular bundle consists of only xylem and phloëm, without the cambium, and so there cannot be secondary thickening and such bundles

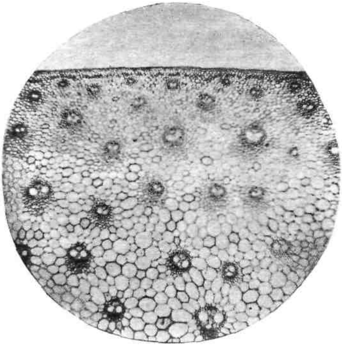


FIG. 111. Transverse section of a monocotyledonous stem. × 80

are called closed vascular bundles, to distinguish them from the dicotyledonous vascular bundles which have the cambium, and hence are called open bundles. A distinct pith or medulla is wanting in the monocotyledonous type of stem on account of the scattered arrangement of the vascular bundles. The cortex is also very narrow. The vascular bundles are far more scattered towards the centre but they are closer near the periphery of the stem.

The vascular bundle consists of only xylem and phloëm. The former consists of only a few vessels, fibres, and wood parenchyma.

The xylem vessels are arranged in the form of a "V" with wood parenchyma and small vessels wedged in between the larger vessels. The phloëm lies close to the xylem. All round the bundle we find fibres forming a kind of sheath, which is well developed and for this reason becomes more marked in the bundles lying near the periphery of the stem.

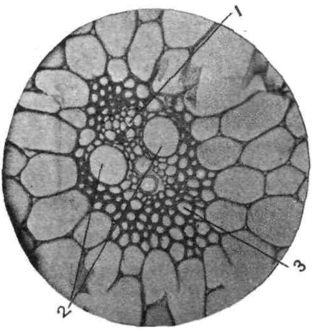


FIG. 112 Transverse section of a single vascular bundle of the Sugar-cane stem 1, sieve tube ; 2, xylem ; 3, fibrous sheath. × 400.

As already noted the cortex is not a very conspicuous part in this type of stem. The epidermis, as well as a few layers of the cortex, lying immediately beneath the epidermis is generally modified in structure. The cell-walls of the epidermis and those of the cells of the cortex immediately below the epidermis become thickened. Further, as already pointed out, the vascular bundles towards the cortex have very broad sclerenchymatous sheaths. So the peripheral portion of the

stem is strengthened by the presence of thick-walled elements enabling it to stand the strain of wind and weight.

The fibres forming a sheath around the vascular bundles of the monocotyledonous stem and the groups of fibres forming a part of the pericycle in the stems of Sunflower and Aristolochia play a very important part in the life of the plant.

They protect the soft elements of the phloëm. The general arrangement of the fibres in all these cases is very *striking and significant.*

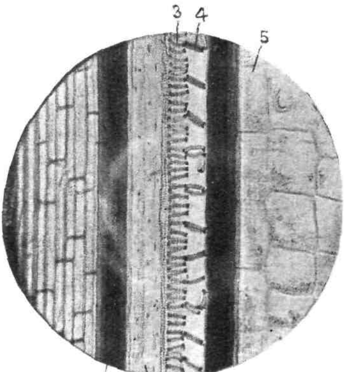


FIG. 113. Longitudinal section of a vascular bundle of the Cholam stem. 1. fibre bundle; 2, pitted vessel; 3, spiral vessel; 4. annular vessel; 5, parenchymatous cells of the ground tissue. × 400.

An engineer or a mechanic will *always try to secure the necessary strength in the materials he uses by the use of the* smallest amount of material. For instance in bridges and roofs instead of using oblong solid beams, girders are used.

A girder consists of two broad pieces, one forming the upper and the other the lower surface with a piece between

called the flange. If an ordinary beam be fixed at one end, the other end being free, and then a weight be attached to the free end the beam will bend at the free end. Then the upper surface becomes longer and the lower shorter. The central line which is equidistant from both the surfaces undergoes no change. So it is obvious that in the beam the upper and

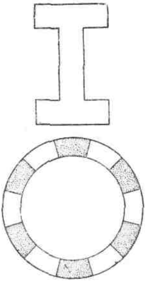


Fig. 114. A girder and a hollow pillar.

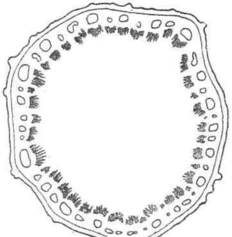


Fig. 115. Fibre bundles in the Sunflower stem. (The larger circles are the fibre bundles and the minute circles in lines are vascular bundles.)

the lower surfaces alone need strengthening, and the flange needs it not. In a girder a great amount of material is used to make the two surfaces strong, and the flange is generally thin. A girder will bear a greater weight than a solid beam containing the same amount of material. Similarly we find that a hollow cylinder will bear a greater load than a solid one containing the same amount of material. The stems of plants are exposed to strain from the action of the wind. As the stem grows larger and larger, the strain that it has to bear increases. The Sunflower stem, for instance, is exposed to the influence of wind and it has to resist the strain of bending. It has also at the same time to carry the weight of leaves, flowers and branches. So there must be in the stem some arrangement which will enable it to withstand

the strain of bending. In a transverse section of the Sunflower stem, we find isolated groups of fibres just close to the phloëm and almost near the periphery. The arrangement of the groups of fibres, in this stem and in this manner, makes it like a hollow cylinder with very great firmness and rigidity at the periphery of the stem. A hollow cylinder is really a combination of several girders.

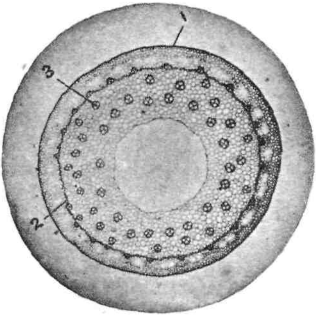


FIG. 116. Transverse section of the stem of *Panicum repens*. 1. epidermis; 2. ring of fibres; 3. fibrous sheath of the vascular bundle.

This kind of arrangement of fibres is seen in many monocotyledonous stems also. For instance, in the stem of *Panicum repens* we find a continuous ring of sclerenchyma and also the fibrous sheaths of the vascular bundles. Where such rings are absent we find the peripheral part strengthened by the thickening of the epidermal cell walls and by the development of a larger number of vascular bundles with very pronounced fibrous sheaths in the peripheral part of the stem. As the stem gets older several layers beneath the epidermis undergo thickening of their cell-walls.

This strength giving tissue, consisting of groups of fibres, is sometimes called mechanical tissue. The fibres come into

existence gradually. So in young stems we do not find these fibres so well formed and arranged. They are either absent or in the course of formation. Younger parts of stems also require a certain amount of strengthening at the periphery as they have also to withstand the strain of wind and weight.

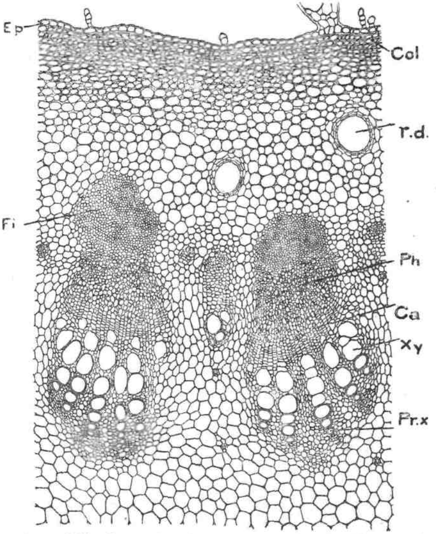


FIG. 117. Collenchyma in the stem of the Sunflower plant *Ep*, epidermis : *Col*. Collenchyma ; *r.d.* resin duct ; *Fi*, fibre bundle ; *Ph*, phloëm ; *Ca*, cambium ; *Xy*, xylem ; *Pr. x*, primary xylem. × 300

As all the parenchymatous cells in the younger parts are active, it is necessary to have some kind of mechanical tissue which would give rigidity and at the same time be elastic, to allow the cells to grow. Fibres are inelastic and rigid.

Therefore they are out of question. Some other kind of tissue should be formed. The parenchymatous cells of the cortex below the epidermis become thickened at the corners where two or three cells meet. These cells form a kind of tissue and we have already spoken of this tissue and it is called *collenchyma*. Thus we have two kinds of tissues to serve as mechanical tissue. Collenchyma consists of living cells and is best suited for young stems, because it changes into ordinary parenchyma when it is no longer needed; the fibres on the other hand are dead cells and so are of no other use.

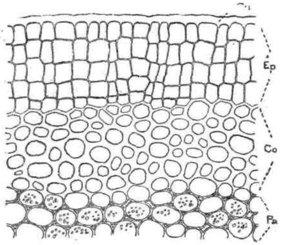


FIG. 118. Collenchyma in the stem of Nerium. (Transverse section.) *Cu*, cuticle; *Ep*, many layered epidermis; *Co*, collenchyma; *Pa*, parenchyma. × 200.

Both the root and the stem of dicotyledons are capable of increase in their thickness to any extent on account of the presence of the cambium. This increase in thickness is called secondary thickening. Under normal conditions growth or increase in the number of cells, which naturally leads to the increase in the different kinds of tissues, is confined to the cambium. But under abnormal conditions parenchyma that has ceased to divide and grow may once again become active and give rise to different kinds of tissues. When a stem is cut across or injured various tissues are exposed to the air. Most of the cells of the cortex are living cells and so, when pressure is removed by the injury, all these cells swell and some of them lying somewhat

deeper begin to divide. As the result of this activity a mass of cells is formed at the injured area and the outermost cells become changed into the protective tissue, cork. This mass of cells brought into existence by this abnormal activity is spoken of as *callus* and the process is termed *callus-formation.* All the wounds caused accidentally or consciously by men in tree trunks and branches get healed by the process of callus-formation.

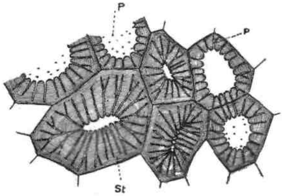


FIG. 119. Sclerenchyma from the stem of Nerium. *St*, laminations ; *p*, pits. × 400.

From a study of the structure of the stem we see that it is only a mass of cells in which are embedded cells or groups of cells variously modified. The main bulk of the stem consists of thin walled parenchyma cells. For the sake of clearness we may classify all the tissues occurring in a plant body as follows :—

(*a*) *The formative tissue*—
(1) Meristem cells of the growing points.
(2) The cambiums.

(*b*) *The protective tissues*—
(1) The epidermis and (2) the cork tissue.

(*c*) *The conducting tissues*—
(1) The lignified vessels and (2) the sieve tubes.

(*d*) *The ground tissue*—The parenchymatous cells.

(*e*) *The mechanical tissues*—
(1) Sclerenchyma and (2) Collenchyma.

(*f*) *Some special tissues*—
(1) Laticiferous tissue.
(2) Resin ducts.
(3) Oil glands and mucilage cells.

CHAPTER VI.

THE LEAF.

THE leaves are the most conspicuous parts of a plant and they are also very important organs of a plant. It is a matter of common knowledge that leaves vary a great deal in size, shape and character. And yet most leaves are delicate and have a thin flattened portion called the blade or the lamina.

A leaf is an outgrowth of the stem like its branches, but with this difference. A branch is merely the repetition of the stem, whereas a leaf differs very much from a stem in its structure. From a study of leaf buds we have learnt that leaves appear as small outgrowths on the surface at the growing points and that they develop in acropetal succession. Leaves are arranged on the stems in definite positions and in some regular order.

A typical leaf has three parts, the blade or the expanded portion, a stalk or the petiole and the basal portion of the leaf which connects the leaf with the stem. All leaves do not possess all these three parts. For instance, we have leaves, such as those of Radish, Lactuca, Sonchus and Argemone without stalks. The leaf blade, on the other hand, is very well developed in most of the flowering plants. Similarly the basal portion of the leaf must be expected to be present in all plants. Young leaves which are enfolded in the bud do not possess stalks, or if they happen to have them they are very short and almost invisible. However, the stalk develops subsequently, and elongates after the unfolding of the leaves. This is so, because in the enfolded leaves the basal portion and the lamina become developed very much earlier than the stalk or the petiole.

From the basal portion of the leaves outgrowths arise in many plants. Generally two outgrowths, one on each side, are seen and they are called *stipules*.

In very many plants the stipules are small and not prominent. There are also plants in which the stipules are very conspicuous and large. The Peepul (*Ficus religiosa*),

the Banyan (*F. bengalensis*), the Jack tree (*Artocarpus integrifolia*) and *Cassia auriculata* have large stipules. In

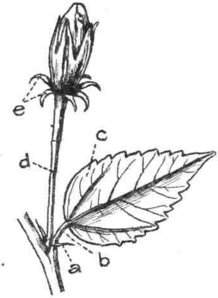


FIG. 120. Parts of the leaf in *Hibiscus Rosa-sinensis*. *a*, stipule; *b*, petiole; *c*, lamina or blade; *d*, peduncle; *e*, bracteoles forming an epicalyx.

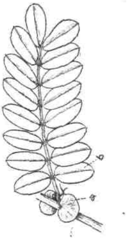


FIG. 121. Parts of the leaf in *Cassia auriculata*. *a*, stipules; *b*, leaflets.

the first three the stipules serve to protect the young leaves in the bud; they are large and semilunar in *Cassia auriculata*. Sometimes they are tubular, as in *Polygonum glabrum*.

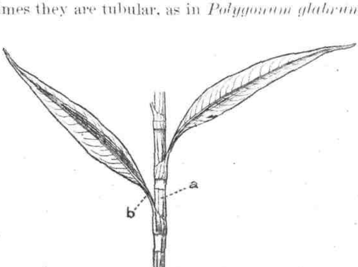


FIG. 122. Tubular stipules of Polygonum. *a*, stipule; *b*, petiole

When leaves are young they are generally folded in different ways. In many plants the two halves of the blade

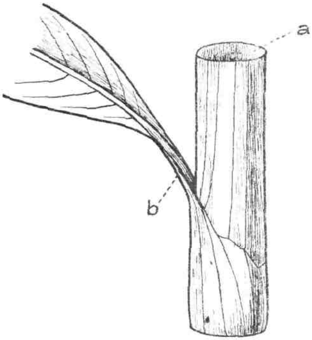


FIG. 123. Tubular stipule of Polygonum. *a*, tubular part: *b*, stalk of the leaf. (Four times the nat. size.)

are folded along the midrib in such a way that the inner surface and the edges of the blade meet, as in Anona, Abutilon, Thespesia, Morinda and Tephrosia. This kind of folding is called *conduplicate*. Sometimes the leaf is rolled on itself in such a manner that one margin being rolled towards the midrib remains inside and the other over it outside, as in Musa and Canna, and the folding is termed *convolute*. It is not unusual to find both the margins of a leaf rolled inwards towards the midrib as in Nymphæa, Nelumbium, Ottelia and Viola and this is described as *involute*,

FIG. 124. Terminal bud of *Ficus bengalensis*, protected by stipules.

As already remarked, of all the vegetative organs of a plant the foliage leaves are the most important, because the

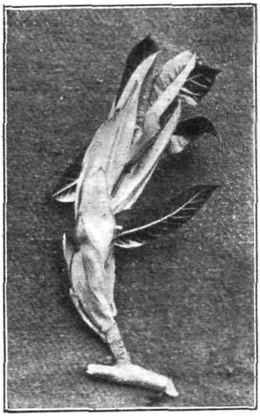


FIG. 125. Young leaves just emerging from within the stipules in the young leaf bud of Ficus.

formation as well as the transformation of organic matter takes place in them. The work that leaves have to do is very complicated and varied. The green colour enables them to do the work of forming organic matter under the influence of sunlight. This special work of the leaf cannot be carried out unless the leaves are exposed to sunlight. So we expect leaves to be disposed on the axis in such a manner that all the leaves may get as much light as possible. And yet too much light is injurious to leaves. The adjustment of the position of the leaves with reference to light is therefore a very delicate one.

In most plants the leaf blades maintain a horizontal position so that a large number of light rays may fall on them. If the light gets too intense, either the leaf blade will

change its position or the twig bearing the leaves will shift its position.

Every green plant produces as many leaves as possible and their position with regard to the light will be such that all the leaves may get sufficient light without shading one another to any large extent. Leaves generally appear to be arranged in various ways on the stem, but on close examination it will be found that either a single leaf *originates at each node, or* two or more spring from it.

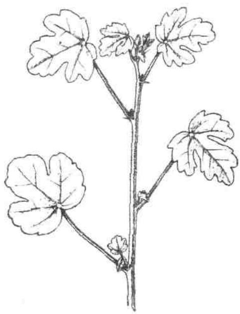


FIG. 126. Alternate leaves of *Pavonia zeylanica*.

When only one leaf is *borne by the stem at the* nodes, the leaves will be found arranged spirally *around the stem or alternately*. This arrangement of leaves on the stem (or *phyllotaxis*) is said to be *alternate*. Leaves are said to be *opposite*, if two leaves arise opposite to one another from the same node. If there are more than two leaves at a node, they are said to be *whorled*. Leaves are opposite in

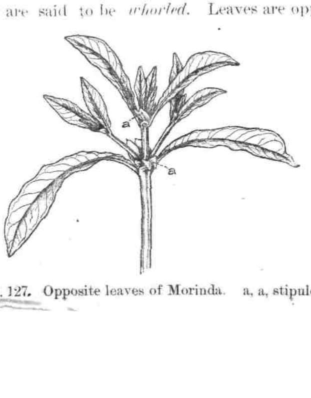


FIG. 127. Opposite leaves of Morinda. a, a, stipules

Morinda, Calotropis, and Vinca. They are whorled in Nerium, Alstonia and Clerodendron. As examples for the alternate phyllotaxis we may mention Thespesia, Abutilon, Pavonia and Melia.

FIG. 128. Opposite leaves of Calotropis.

In stems with alternate leaves no two successive leaves will be found to be one exactly above the other and yet, the leaves will be in vertical rows. Between two successive leaves on the same vertical line, a number of leaves will be found, but at different heights and in different positions. To make out the arrangement of the leaves in such cases, a close examination of the nodes of a normally growing shoot is necessary. As an example a branch of Thespesia, or Abutilon may be taken. In these branches any leaf chosen will be exactly above or below the sixth leaf and the five leaves spirally arranged round the stem. The spiral will consist of two turns around the stem and the

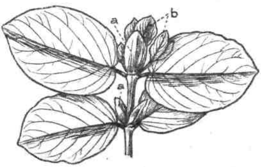


FIG 129. Opposite leaves of Stephegyne. a, stipules : b, young leaves.

first leaf will be separated from the second by a space equal to two-fifths of the circumference. If the circumference were one inch the first leaf will be two-fifths of an inch apart from the second, and the second the same distance from the third and so on. In a spiral of five leaves we get five vertical rows arranged round the stem at equal distances. We also meet with spirals having two, three, or four leaves or more.

When the leaves are opposite the successive pairs will be at right angles to one another. In other words the leaves at

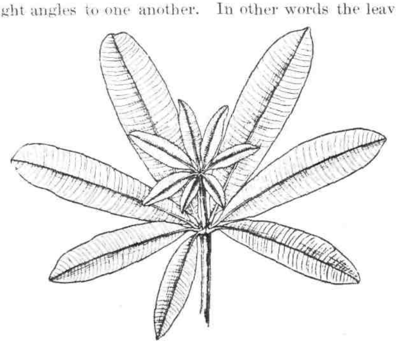


FIG. 130. Whorled leaves of *Alstonia scholaris*.

any one node will be across the leaves of the nodes immediately above and below it. This arrangement of the leaves is called *decussate* arrangement. (See fig. 128.) When the leaves are in a whorl, the leaves of the alternate nodes are exactly one above the other, and the leaves of the successive nodes will be found on different vertical lines side by side.

The phyllotaxis will become clear, only if we remember that the leaves require the play of sunlight on their blades. Usually the most advantageous position for the leaf blade is to place its surface across the direction of the rays of light. But if the light becomes very intense, this position is certain to injure the leaf blade. So, under such circumstances, the leaf should be able to shift its position. When the sun's rays pour

straight down, the leaf will shift its position, so that the blade may be parallel to the rays instead of being at right angles. *Almost all leaves possess the power of changing their position according to the nature and the intensity of the light of the sun.*

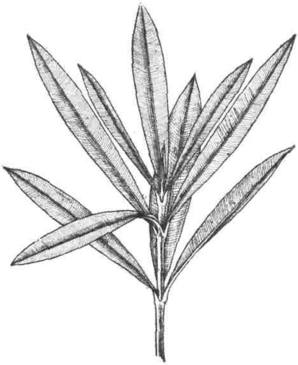


FIG. 131. Whorled leaves of Nerium.

As all the leaves of a plant need light, it is obvious that they should grow in such a manner, as not to shade each other. One of the means by which the leaves are helped in this matter is the phyllotaxis. There are also other means, besides the phyllotaxis, by which the leaves avoid the shading. Choose some erect branches from a plant, say *Acalypha indica* or an Amaranth, and look down upon them from above. Then the leaves will be found arranged in rows round the stem, in such a manner that the space round the stem is utilised to the greatest possible extent. Further, the leaves below are not shaded by those above, because the petioles of the former are longer than those of the latter. Again the size of the leaf blade also has some bearing on the disposition of the leaves around the stem. If the leaves

have broad laminas, the rows round the stem will be three or four: there will be five or six rows, when they are moderately broad: the rows will be many in cases where *the blade is very narrow*. Whatever the number of rows around the stem, all the leaves get their share of light, because the rows are not likely to shade one another. But, in the same row, leaves above are likely to throw those below into shade. As a matter of fact this does not happen so as to *interfere with one another*. By the adaptation of the length of the internode and the direction and length of the leaf-blade, shading is avoided.

Thus it is seen that the adjustment of the leaves for the sake of light is very varied and complicated. In some cases the leaf surfaces present beautiful mosaics and rosettes. For *instance in many* Solanaceous plants, such as *Physalis minima*, the leaves are not all uniform in size and so the leaves arrange themselves in a mosaic *fashion*.

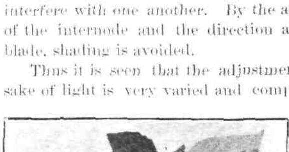


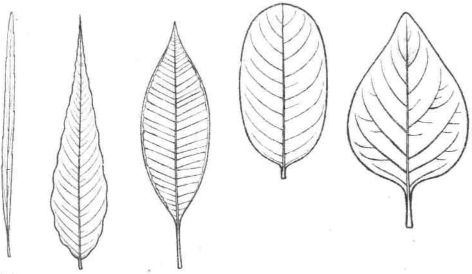
FIG. 132. Leaf mosaic of *Physalis minima*

Many plants of the order Compositæ may be cited as examples for the rosette habit of the leaves. The leaves in *Lactuca Heyneana*, Sonchus and some Blumeas are mostly confined to the base of the plant. In other words, the leaves are radical. In all these plants *the leaves are narrow at least in the lower part and so they* are disposed round the stem, so as to form a rosette. It is easy to give more examples: for instance Trapa, Elytraria and *Elephantopus scaber*.

The same principle, that the leaves should spread themselves so as to enable all the leaves to be lighted and, at the same time, avoid shading one another, is very well brought home by the heads of trees. For instance, the heads of trees

such as those of the Banyan are generally found covered by leaves so as to form a framework or covering with as few gaps as possible. To enable all the leaves to obtain sufficient light, this is the best possible arrangement. If we look at the head of the same tree from inside and from near its trunk towards the branches, we find large spaces between boughs and twigs, and no leaves are found distributed in these gaps.

FIG. 133. Leaf mosaic of Fittonia.

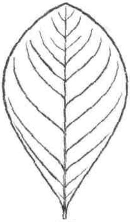


134 135 136 137 138

FIGS. 134 to 138. Shape of leaves ; linear, lanceolate, elliptic, oblong and ovate leaves.

Shape of leaves.—Leaves vary very much in their shape. For purposes of description names are given to the shapes that are striking. A leaf whose lamina is narrow with the sides parallel, is said to be *linear*. Leaves of grasses and those of the cereal plants are linear. When a leaf is

somewhat broad at the middle or a little below and tapers towards the apex, as in Nerium, Polygonum and Polyalthia it is described as *lanceolate*. A leaf is *oblong* when the margins are almost straight and the blade uniformly broad. Guava, Calotropis and Banyan leaves are good examples of oblong



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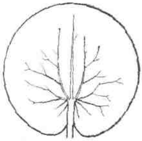

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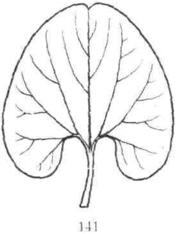

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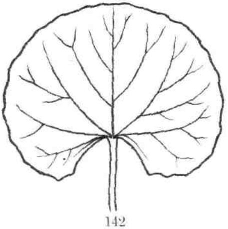


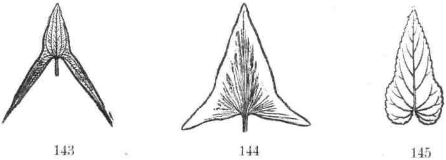
142

FIGS. 139 to 142. Shape of leaves; obovate, orbicular, cordate and reniform.

leaves. When the leaf blade is broad and rounded at the base and also tapering to a point at the apex, it is described as *ovate*. Leaves of *Hibiscus Rosa-sinensis*, *Acalypha indica*, *Solanum nigrum* and *Physalis minima* are good examples. When the blade is broader at the apex and narrowed towards the base, as in the leaflets of *Cassia obovata*, it is *obovate*. Leaves like those of Nelumbium are described as *orbicular* or *rotund*. Sometimes the blade is hollowed out at the base,

and pointed at the apex so as to be roughly like the heart spot on a playing card, and such are called *cordate* or *heart-shaped*. The leaves of Thespesia and Aristolochia may be cited as examples. If the apex be rounded, instead of being pointed, the outline is said to be *reniform* or *kidney-shaped*. The leaves of *Hydrocotyle asiatica* are reniform. There are some leaves whose lamina resemble somewhat an arrow head in their shape, and such leaves are *sagittate*. Several species of the Natural order Aroideæ have sagittate leaves. If the basal lobes of such a blade are straight and at right angles to the blade, the leaf is then *hastate*. If the basal lobes are rounded and prominent, the leaf is said to be *auricled*.

Margin of leaves.—The leaf margin is *entire*, when it is quite even without any indentations. It is *dentate*, if the margin is cut up into prominent teeth, as in *Hibiscus Rosa-sinensis*; *serrate* if the teeth are small and directed upwards, as in *Acalypha indica*; *crenate* when the teeth are rounded, as in *Bryophyllum calycinum*, *Hydrocotyle asiatica* and *Stachytarpheta indica*. Sometimes the margins of leaves become deeply indented and then the leaf is said to be *lobed*, if the cut does not go more than half way to the centre, as in the cotton leaf, and if it is deep reaching the middle of the leaf, as in Lactuca and Radish, then the leaf is said to be *cleft*.



143 144 145

FIGS. 143 to 145. Sagittate, hastate and auricled leaves.

When a leaf is lobed, the lobes are arranged either on the sides of the midrib as in Lactuca and Radish, or they may all spread like the fingers of a hand, as in Jatropha and *Hibiscus ficulneus*. The former is described as *pinnate* and the latter *palmate* or *digitate*. Sometimes the lobing becomes so deep as to cut the blade into distinct pieces so that a piece may be

plucked off without in the least affecting the others. In such cases the leaf is said to be a *compound leaf*. The leaflets may either be disposed pinnately as in *Cassia auriculata* and *Cassia siamea* or palmately as in *Eriodendron anfractuosum* and *Gynandropsis pentaphylla*.

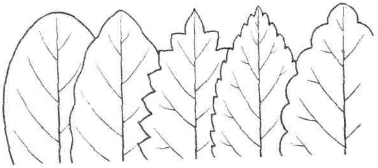


FIG. 146 Leaf margins. Entire, undulate, dentate, serrate and crenate margins respectively.

The division of lamina may take place only once and then the leaf is simply compound, or the leaflets may become divided further, as in the case of Moringa, Cardiospermum, *Acacia arabica*, *Melia Azedarach* and *Millingtonia hortensis*. Then the leaf is described as bi- or tri-pinnately compound according to the division.

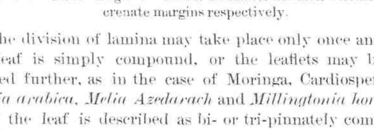


FIG. 147. Leaf apex. Acuminate, acute, obtuse, truncate, retuse, cuspidate and mucronate respectively.

Apex of leaves.—If the apex of a leaf tapers to a point gradually it is said to be *acuminate*, and if it is merely sharp pointed it is *acute*. The apex is *obtuse*, when it is rounded. Sometimes the apex will be straight as though cut off and then it is *truncate*, and if there is a notch it is said to be *retuse*, if the notch is shallow and *emarginate* if it is deep. In some cases we see a sharp point projecting from the apex and then it is said to be *mucronate*. We meet with leaves having a triangular piece at the apex and then it is said to be *cuspidate*.

Kinds of leaves.—The organ directly concerned in the work of manufacturing organic substances is the foliage leaf. This is the kind of leaf which is of very general occurrence. Sometimes leaves are forced to do some kind of work, other than the preparation of organic substances. For instance, in seedlings, the cotyledons in most cases have very little to do, at any rate in the beginning, with the work of making organic stuff. The work that the cotyledons are mainly concerned in is to store food and make it available to the growing seedlings.

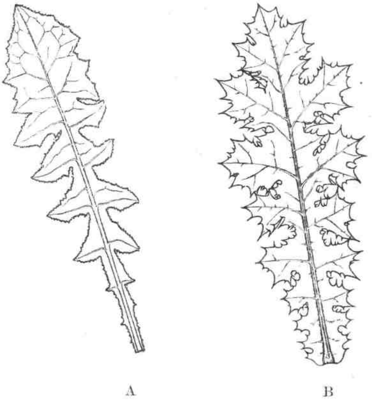


FIG. 148. Pinnately lobed leaves of A, Lactuca and B, Argemone.

Another kind of leaf occasionally met with in some plants is what is known as the scale-leaf. These leaves are met with in connection with scaly buds. In Mango trees when growth is at a standstill the terminal buds at the ends of twigs are covered by small scales. These scales are really leaves remaining undeveloped and small so as to afford protection to the growing point. (See figs. 82 and 83.)

And yet another kind of leaf is the bract found in connection with the flower. Bracts are generally small, but in some

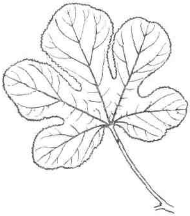


FIG. 149 A digitately lobed Hibiscus leaf.

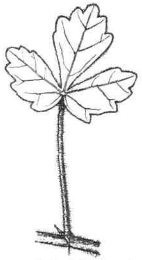


FIG. 149-A. A digitately deeply lobed leaf of Pavonia.

plants they are large. For instance, in the terminal branches of the plant *Gynandropsis pentaphylla*, the foliage leaves gradually pass into bracts and so, they are very conspicuous and leaf-like.

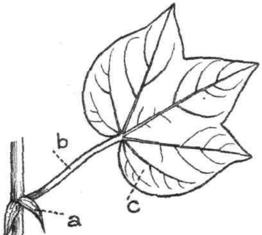


FIG. 150. Digitately lobed Cotton leaf. *a*, stipule; *b*, petiole; *c*, blade.

Modified leaves.—There are a number of plants feeding on insects. They do not thrive well, unless they obtain insects. In these plants there are adaptations of a special kind

to enable them to catch and digest small insects. As examples of such plants we may mention Drosera (*D. Burmanni*,

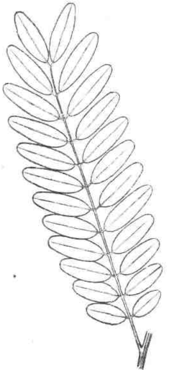


FIG. 151. Paripinnate compound leaf of *Cassia siamea*.

FIG. 151-A. Impari-pinnate leaf of *Melia Azadiracta*.

FIG. 151-B. Bi-pinnately compound leaf of *Acacia arabica*. *a*, stipulary thorn ; *b*, petiole ; *c*, gland.

D. peltata and *D. indica*), Utricularia (several species) and the pitcher plant Nepenthes. In Drosera the leaves are provided with glandular hairs secreting mucilage in such profusion as to imprison the insects, when the hairs come in contact with them. The leaves of Utricularia are modified into bladders with trap doors to catch insects. In the pitcher plants the leaves are prolonged at the apex into long processes ending in cups. These cups or pitchers as they are called, contain a liquid. The insects are allured by these pitchers so that they may fall into them and get digested by the water contained therein.

FIG. 152. Palmately compound leaf.

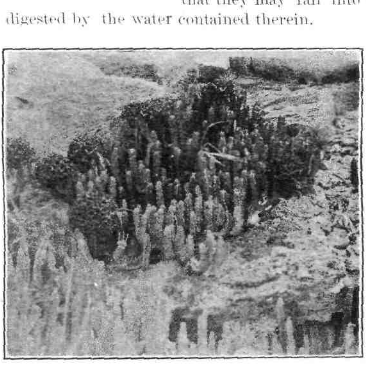


FIG. 153. Boucerosia. Note the leafless fleshy stems (cladophylla).

Leaves are able to produce organic matter, as they contain chlorophyll. Young parts of plants are also able to do this because they also contain the green colouring matter. There are many plants without leaves, as in the case of the Pricklypear. In such plants the chlorophyll grains become imbedded

in the cells of the cortex of the stem. Such stems look quite different from the ordinary stem and they are called *cladophylla*.

In some leaves the petiole develops into a flat structure very much resembling the leaf and the blade either remains very insignificant, or it is not at all developed. Such petioles are called *phyllodes*.

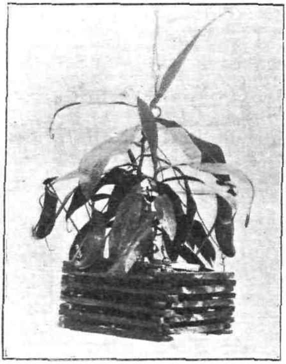


FIG. 154. The Pitcher plant.

As examples of cladophylla we may mention the stems of Boucerosia, Opuntia, Casuarina and some Euphorbias. Phyllodes are found in *Acacia auriculiformis* and in *Parkinsonia aculeata*.

Petioles have sometimes wings on both sides as in the orange leaf and in the compound leaves of some species of Vitex and *Filicium decipiens*.

The internal structure of leaves.—The leaf-stalk or the petiole does not differ much from the stem in internal structure. In the petiole the vascular bundles are arranged generally like a semicircle, especially the larger ones. There are also smaller bundles between the larger ones. The cambium does not persist in these bundles, because there is no

need for secondary thickening. The xylem lies towards the upper surface and the phloëm towards the lower.

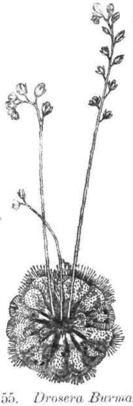


FIG. 155. *Drosera Burmanni.* The entire plant.

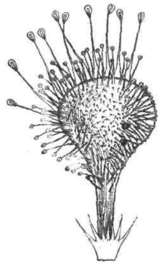


FIG. 156. A single leaf of *Drosera Burmanni* with glandular hairs. (Five times the nat. size.)

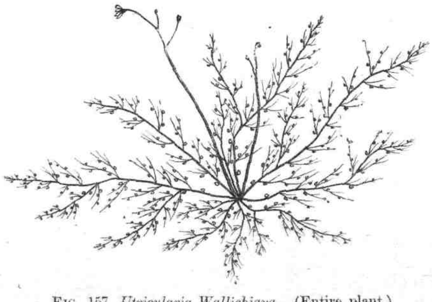


FIG. 157. *Utricularia Wallichiana.* (Entire plant.)

The lamina of an ordinary leaf consists of a mass of parenchymatous cells filling up the meshes of the network of veins, which is a prominent feature of the foliage leaves. This network of veins not only supports the leaf tissue, but also serves as a channel for carrying water to the cells in the meshes of the network. It also prevents the tearing of the leaf blade and keeps it quite flat. As striking examples of the network of veins, we may mention the leaves of *Ficus religiosa*, Quisqualis, Dolichos and Antigonon.

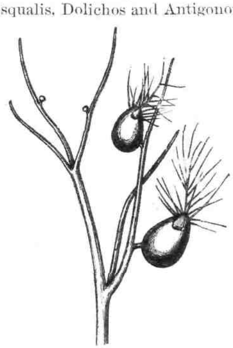


FIG. 158. A branch of *Utricularia Wallichiana*, with bladders. × 10.

A leaf considered from an anatomical point of view consists of three parts. They are an epidermis covering both the surfaces of the blade, the mass of parenchymatous cells having chloroplastids imbedded in them and the network of veins.

The epidermis consists of flattened cells all fitting closely together, and they do not contain chlorophyll grains. The lower epidermis differs from the upper epidermis in having the characteristic openings, the *stomata*. Each stoma (which simply means a mouth) consists of a pair of semilunar cells bounding the opening. These cells are called the *guard cells* and they contain chlorophyll grains. Further these

guard cells are capable of changing their shape and so vary the size of the opening. These stomata are generally confined to the lower epidermis of leaves but there are also leaves having stomata on both sides. The number of stomata is generally very large and it may be anything from 50,000 to 450,000 or more to the square inch.

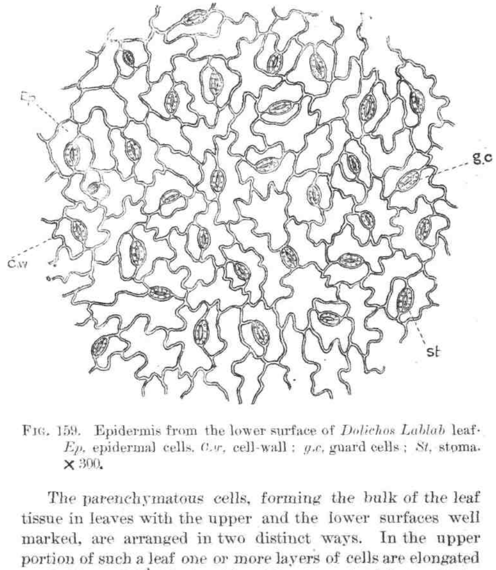


FIG. 159. Epidermis from the lower surface of *Dolichos Lablab* leaf. *Ep*, epidermal cells. *C.w*, cell-wall; *g.c*, guard cells; *St*, stoma. × 300.

The parenchymatous cells, forming the bulk of the leaf tissue in leaves with the upper and the lower surfaces well marked, are arranged in two distinct ways. In the upper portion of such a leaf one or more layers of cells are elongated vertically and lie side by side without much of intercellular space. This is called the *palisade parenchyma*. The parenchyma lying below the palisade parenchyma consists of cells arranged so as to have a large number of spaces, and hence this part of the mesophyll is termed *spongy parenchyma*.

This distinction of the mesophyll, into a compact palisade parenchyma and spongy parenchyma, is liable to variations

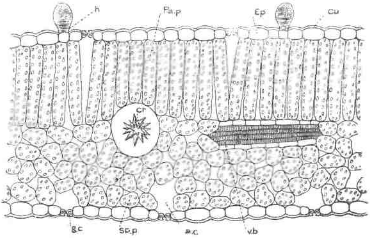


FIG. 160. Vertical section of Gogu leaf. (Highly magnified.) *Cu.* cuticle; *Ep.* epidermis; *h.* glandular hair; *Pa.p.* palisade parenchyma; *Cr.* calcium oxalate crystal; *sp. p.* spongy parenchyma; *v b.* vascular bundle; *a.c.* air chamber; *g.c.* guard cells of the stomata. × 400.

according to the habit and the species of the plant. In the leaves of a plant growing in an open place exposed to the

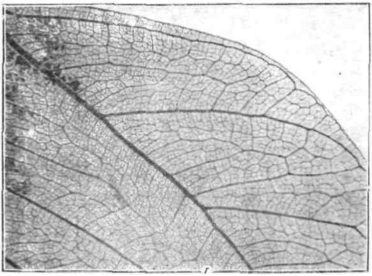


FIG. 161. A portion of the "skeleton" of a leaf of *Ficus religiosa.*

sun, the palisade parenchyma will be deep and will consist of several layers of cells, e.g., leaves of Nerium, Calotropis

and the Banyan. Plants growing in a shady place have leaves with a single layer of palisade cells, e.g., Vigna and Dolichos. In the case of plants whose leaves are exposed to the light of the sun on both the sides, this separation of the mesophyll into two kinds of parenchyma does not exist. For instance, the leaves of grasses do not show this separation but the whole of the mesophyll consists of compactly arranged parenchymatous cells.

The most prominent structure in a leaf is its network of veins, and this part may very well be observed by allowing leaves of plants to rot. The mesophyll and all the soft tissues decay, leaving only the hard vascular frame work. This network of veins is sometimes called the "skeleton" of the leaf. (See fig. 161.)

CHAPTER VII.

THE WORK OF THE VEGETATIVE ORGANS OF A PLANT.

As a plant is a living organism we should expect its life to be similar to that of an animal in all essential respects. Like animals plants also have to eat, and without food they cannot live. We know, from the study of seedlings, that a young plant gets its food from the cotyledons or the endosperm. But very soon this source of supply fails, and it is forced to obtain food from other sources.

A very young plant still in the course of development does not show the characteristic features of vegetable life, until it begins to lead an independent life, i.e., until the roots penetrate the soil so as to get a firm hold, and the shoot stretches into the air towards the light. A plant is capable of living independently, as soon as foliage leaves are formed.

When we recall to our mind the main structural features of a flowering plant, it at once becomes obvious that all the food materials that a plant needs must get into the interior of the plant body, either as a liquid, or as a gas. Further, it must obtain everything it wants, either from the atmosphere, or from the soil. It is evident that substances in the soil needed for the plant have to get into the plant body only through the roots.

For a clear understanding of the kinds of substances absorbed by the root from the soil, and the manner of absorption, we should learn something about the soil.

Soils in which plants grow usually consist of two substances : (1) humus or organic matter resulting from the decomposition of plants and animals, and (2) mineral matter chiefly consisting of sand and clay in various proportions. Humus gives to the soil a loose open texture and it is capable of retaining a very large amount of water, besides containing plenty of plant food.

In most soils we find sand, clay and humus ; but these vary in their relative proportions in different places. A soil is said to be sandy, if the proportion of sand is high ; and

such a soil is more open, more porous, warmer and drier than clay soils. A pure sandy soil is of no use to a plant, for practically it contains nothing that is likely to be of use to the plant. A soil containing a large amount of clay with a very small quantity of sand is called a clay soil. And this soil tends to form a hard compact mass and so the roots of plants cannot penetrate it. When wetted it becomes sticky in texture, impervious to water and impenetrable to the roots of a plant. It is possible, by a proper admixture of humus, clay and sand, to obtain soils of any desired consistency or texture, and also of any grade of fertility.

Soils may be classified as follows :—

Sandy soil	... ...	*80 to 100*	*per cent.*	*sand.*
Sandy loam	... ...	50 to 80	,,	,,
Loam ...	... ...	40 to 50	,,	,,
Clay loam	... ...	20 to 40	,,	,,
Clay ...	... ...	0 to 20	,,	,,

A soil which is good for growing plants will contain a certain amount of water : and this water will generally exist as isolated drops held by the soil particles between them and it may also remain as thin films adhering to the soil particles. The remaining space is filled with air. (See fig 48.) For the proper development and growth of the root-systems of land plants, this air is absolutely necessary. When the soil is water-logged through lack of drainage, this air is excluded and the root-systems of these plants suffer very much.

The work of the root.—In the embryo plant which is just trying to come out of the seed, the part which develops first is the root. It is so, as the plant needs water for growth, and water is available only in the soil, and therefore, the roots of plants find their way into the soil. Thus from the very commencement roots have not only to take on themselves the work of absorbing water from the soil but they have also to fix the plant in the soil. We must now try to learn how a root absorbs water and which part of it is actually concerned in this work.

Absorption of water is an essential feature of a living cell. Plants of low organisation and submerged aquatics absorb water through the entire surface of their bodies. In land plants this work is restricted to the root-hairs.

A root-hair is merely a living cell very much elongated so as to increase the surface of absorption. Like an ordinary cell it consists of a cellulose membrane enclosing a vacuolated protoplasm. We know that protoplasm will be active only when there is water. And so it should have an inherent capacity to absorb water.

The process of absorption really consists of three distinct processes, viz., imbibition, osmosis and protoplasmic absorption.

The cell-wall of the root-hair is highly hygroscopic and consequently it adheres very firmly to the soil particles. The film of water round the soil particles gets into the cell membrane by overcoming the cohesion of the molecules of the cell-wall. The cell-wall swells and even becomes mucilaginous as a result of this entrance of water into it. Water enters the protoplasm also, and thus makes both the cell-wall and the protoplasm more porous. This is obvious because there is swelling. All these are included under the term *imbibition*.

By mere imbibition the process of absorption cannot go on continuously. There must be some other force at work to ensure continued absorption of water. It is a well-known fact that when two fluids or solutions of unequal density are close together and only separated by a porous membrane, the fluids or the solutions will get through the membrane and mix with each other. At first the weaker solution will flow towards the membrane and get into the stronger solution, and later on the stronger solution will diffuse through the wall into the dilute solution. This double diffusion through the membrane will go on until the density is same on both the sides. *This process of diffusion is usually spoken of as osmosis.* The diffusion into the denser liquid is termed *endosmosis*, and that in the reverse direction is called *exosmosis*.

A root-hair is a membranous bag filled with water in which various substances are dissolved. The film of water adhering to the soil particles is a weaker solution compared with the water inside the cell-wall. And according to the physical laws of osmosis, water in the soil will flow into the root-hair through the cell-wall. The porous wall will also be wetted by the cell-sap from inside, and the cell-sap being denser will

tend to diffuse into the soil. If this goes on continuously there will be no absorption of water into the plant. The *ordinary process of osmosis is modified in the root-hair of a plant in such a manner that water will be allowed to diffuse freely into the root-hair, but the diffusion of the cell-sap from the root-hair into the soil is rendered difficult, if not impossible.* The protoplasm lining the wall of the root-hair allows endosmosis to go on, as it has a great affinity for water. But the current in the reverse direction (exosmosis) will be extremely slow. Generally the cell-sap flowing outwards is very small in quantity and is acid in reaction. This acid reaction is due to the presence of carbonic acid. The roots of land plants, according to the researches of scientists, do not seem to excrete any free acid except carbonic acid. The solvent action of the root is entirely due to the action of the carbonic acid.

The protoplasm of the root-hairs, in addition to the power of modifying the ordinary process of osmosis, may be said to have the power of selection as well. Water is very rarely absorbed as it exists in the soil. *The protoplasm has not got the same affinity for both water and salts. It has a greater attraction for molecules of water when there is more salt, and will take in more salt when the water is dilute.* This selective power of protoplasm in the root-hair, by which it takes up water and soluble salts without strict regard to their proportion, is of very great importance to the plant.

The flow of water from the root-hair into the adjoining parenchyma cells of the cortex is in accordance with the ordinary laws of osmosis. From the cortex water gets into the vascular bundles.

Soon after absorption of water, a cell becomes turgid and the internal pressure becomes greater. All the parenchymatous cells of the cortex of the root become turgid. The pressure in all these cells increases and this pressure is called *the root-pressure.*

In several plants the root-systems have other functions besides the normal function. For instance in Ipomœa Batatas the roots swell and begin to store starch. As other examples we may mention the roots of Radish, Carrots, etc. Sometimes roots help the plants in clinging to supports.

Roots of land plants possess the power of reacting to the external conditions and accommodating themselves to them. Their growth and development depend upon many conditions. The amount of water in the soil, its quality and concentration, amount and character of the food material, the temperature of the soil and its aeration are the factors that influence the development of roots. Roots are always highly sensitive to moisture, and this is expressed by saying that roots are hydrotropic. Young roots have always a tendency to go towards places where there is water, even overcoming geotropic tendencies, if necessary.

The power of adaptation possessed by the roots is of great use to the life of the plant. Typical land plants have roots that are capable of normal growth even when the medium of the root-system is changed from soil to water. Hence water culture experiments are possible.

The formation of the root-hairs should also be considered as they are the organs directly concerned in the work of absorption. A dry soil is not favourable for the development of root-hairs; but in an atmosphere saturated with water vapour the development of root-hairs is most marked. Soil conditions most unfavourable for the development of root-hairs are lack of moisture, resistance of anything that is hard and too high a concentration of the water in the soil.

The development of the root-system as regards its shape and position depends also upon the kind of the plant, provided that the root-system is adapted to the external conditions as far as it is possible. For instance, the roots of a Cholam plant springing from the seed sown in the soil at the usual depth, as well as those of the same plant sown somewhat deep develop in the same layer of the soil. If the rhizomes of Canna or Curcuma are planted very deep, the new branches arising from the deep rhizomes are all directed upwards until they attain the normal depth of the soil.

The work of the stem.—The stem grows above the ground and so its medium is air. Just as the root-system absorbs water from the soil the shoot-system takes in something from the air. Evidently the materials absorbed by the shoot-system must be quite different from those absorbed by the roots. The root-system should have a large amount of

surface for absorption, and it is the root-hairs that bring about this increase. The shoot-system bears as appendages leaves and they are the parts that take in substances from the air. So the leaf surface is the most important part of the shoot. In all land plants there are two surfaces, the root-surface and the leaf-surface. These two surfaces must be in constant intercourse. And these two surfaces are connected by the stem.

In all ordinary plants the leaf-surface and the root-surface have the stem between them. But this intermediary organ, the stem, is not a very essential organ to the plant, in the same way that the leaves and roots are. We have instances of plants having stems that are poorly developed, as in Crepis, Taraxacum, or the Radish. In all these the leaves lie almost flat upon the ground.

The water absorbed by the root-system gets into the xylem of the root and, as this is continuous with the xylem of the stem, it passes into the stem. The vascular bundles of the stem are prolonged as veins to all parts of the leaves. They may be compared to a series of pipes, serving to collect the water absorbed by the root, to carry it with relatively slight loss through the stem and to distribute it to all parts of the leaf. Thus transport of water is one of the duties of the stem.

That water is transported in the stem and the leaf, only through the xylem, can very easily be demonstrated by a simple experiment. Place a fairly well developed seedling of any plant in water coloured red with eosin, and after an hour or two examine transverse sections cut through the stem and root. In the stem the xylem alone will be red, whereas in the root all the parts, root-hairs, the cortex and the xylem will be stained red.

It must not be forgotten that the stem has to support leaves, buds, flowers and fruits besides being the channel for the conveyance of water.

The upward movement of water through the xylem cannot be due to osmosis, because the xylem elements have all thick walls. But instead, imbibition and infiltration are possible. The chief cause of this upward movement of water is still an enigma, as none of the explanations so far advanced

are satisfactory. Root-pressure, capillarity, evaporation from the leaf surface and osmotic pressure are undoubtedly the probable causes. Of these the most important factor is the evaporation of water from the leaves. When a cell loses water by evaporation, the loss will immediately be made good by the passage of water into this cell from the neighbouring cell. This second cell will affect the third cell and this in its turn the fourth and so on. The loss of water from a cell by evaporation makes the cell-sap denser and this leads to the increase in the osmotic pressure in the leaf cells. The effects of transpiration will be felt by all the cells from the root upwards. In conclusion, we may safely consider the transpiration to be one of the chief factors concerned in lifting the water up the stem.

The work of the foliage leaves.—The part played by the leaf and its importance to the life of the plant was not known, until the end of the eighteenth century. Before that period the leaf was considered to be a useless organ. But now we know that the leaf is as important an organ as the root, nay even more important. It is the leaf that prepares for the plant its chief food. So an eminent botanist says that "the leaf embodies the very essence of a plant life."

To understand the work of the leaf it is necessary to recall to our mind the main features of its structure. The *mass of parenchymatous cells forming the bulk of the leaf* are held together and kept in position, by the network of veins, and covered over on both the sides by the epidermis. Stomata are most abundant in the lower epidermis. They are either fewer in the upper epidermis or they are absent. There are air cavities immediately below the stomata.

The foliage leaf is an organ specially adapted for the reception of light and asborption of gases. It is also the chief place for the loss of water by evaporation.

Of all the organs of the plant, it is the leaf that needs water in large quantities. The water absorbed by the root reaches the veins of the leaf, and from there it passes to the parenchymatous cells. The thinness, flatness, the horizontal position and the arrangement of the parenchyma are favourable conditions for the evaporation of water from the leaves. However, evaporation does not seem to take place all

through the surface of the leaf. The actual transpiring surface is the surface of the cells bordering on air spaces both in palisade and spongy parenchyma. Water escapes into these air spaces and then this gets out through the stomatal openings into the air. This escape of water as vapour leads to the concentration of the cell-sap in the cells bordering the air cavities, and water from the neighbouring cells will diffuse into these cells. As this process takes place in all the cells, there will be a sort of backward suction which may be considered as one of the chief causes for the ascent of water.

The amount of water transpired by the leaf surface of a plant depends upon the structure of the leaf. A leaf having a loose structure possesses a large number of air spaces, and consequently transpiration from such leaves will be very rapid. There are several other factors influencing transpiration.

Moisture in the air affects the process. If the air is dry, loss of water will be greater : if saturated with moisture, transpiration will be retarded considerably, if not entirely stopped. If the temperature of the atmosphere be high, transpiration will be rapid and when the temperature is low, the amount of transpiration will be reduced very greatly. Leaves lose more water when there is wind ; but on a calm day there will not be much loss.

The stomata play an important part in the regulation of transpiration. The guard cells of the stomata are capable of movement and by this means the opening may be varied. The factors concerned in causing these movements are light, humidity and water content. The mechanism by which the opening is narrowed or widened is very simple. The guard cells are fixed at their ends but the inner and outer walls are free. As these cells are generally active, especially in the presence of light they draw water from the epidermal cells that are adjoining. The result of this activity of the guard cells is to cause the inner walls to become more and more convex. We know that these cells are firmly joined to each other at the ends, so the increased turgidity forces them apart. If the evaporation tends to increase, or if the water-supply is inadequate, the guard cells lose their turgidity and the inner wall becomes less convex and the strain on the guard cell is removed and consequently the opening is narrowed.

The amount of water transpired by a plant can be determined very easily by weighing the plants growing in pots. Before weighing they should be covered so as to prevent evaporation from the pots. Several experiments bearing on the question of transpiration may be devised.

The leaf with its delicate active cells is exposed to many dangers. Of such dangers the foremost are drought, strong light and cold. Plants growing in a dry region are in danger of losing much water by transpiration and, unless they develop some means to protect themselves against excessive loss of water, they run the risk of extinction. By a close examination of plants growing in a dry region, it will be seen that the means adopted by them for protection are most varied. But they are all intended to lead to the same result, the reduction of the transpiring surface. The epidermis is always ready to check undue evaporation by developing a thick cuticle. There will also be a great reduction in the number of stomata. The palisade parenchyma becomes very much pronounced by becoming vertically elongated and by increase in the number of layers. Outgrowths such as hairs, scales, waxy bloom, etc., are also means of protection. In some cases the leaves become reduced, and in others leaves do not at all develop.

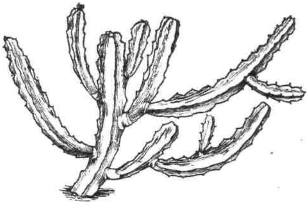


FIG. 162. Boucerosia.

The entrance and the evaporation of water from the leaf are only means to an end, and this end is the manufacture of organic substances. Water brought into the leaf by the transpiration current contains several salts in very minute quantities. As water escapes in the form of vapour, there will be a certain amount of concentration of salts in the parenchymatous cells of the leaf. This concentration enables the cells to obtain a sufficient amount of salts and at the same time causes more water to diffuse into these cells,

All plants, like animals, need food for their growth and development; and the substances used by plants, as well as animals, as food, are the organic substances starch, or carbohydrates, proteids and water. Animals obtain these substances from plants or other animals. Except water, the other substances cannot be obtained by plants from the soil. From the materials supplied by water absorbed by the roots and from carbon dioxide, leaves are able to make carbohydrates, and from this substance proteids can readily be prepared.

In a germinating seed the growing embryo gets its food from the cotyledons or the endosperm, where it is stored. This source of supply lasts only for a short time. As soon as green foliage leaves appear the plant will be able to prepare its food. If it is capable of doing this, we should be able to detect one or other of these stuffs, in the leaves. In plants we find starch in all parts. And its presence can be made out by the use of an aqueous solution of iodine. Starch turns blue on coming into contact with iodine, and, therefore, it is easy to demonstrate the presence of starch in leaves by the use of iodine. Obtain some foliage leaves from a plant which has been growing in the light and steep them in hot water for sometime. Next immerse these leaves in alcohol until they become white. Select one or two of the leaves thus bleached and place them in a shallow dish containing iodine solution. After a while they turn blue, or black according to the amount of starch present. If we examine a leaf taken from a plant kept in the dark for sometime for starch, we do not find any. Therefore we have to infer that starch makes its appearance only when the leaf is exposed to light.

On exposing a starch-free leaf, detached from a plant kept in darkness for some time, to light by placing the leaf in a vessel containing water, starch will be found in it. From this simple experiment it follows that starch is formed in green leaves. Further, it must be remembered that formation of starch takes place only in parts of leaves actually bathed by the rays of light. Portions of leaves not exposed to light, even though contiguous with the parts exposed to light, are free from starch. These facts can be demonstrated by exposing a leaf for a day, after covering it with a stencilled

plate or paper. A leaf thus exposed, when bleached and immersed in iodine solution turns blue only in places exposed to sunlight and the portions covered and not exposed remain clear showing the absence of starch. (See fig. 163.)

Starch is an organic compound consisting of the elements carbon, oxygen and hydrogen. We know that there is plenty of water in the foliage leaves, and this is the *source of the two elements* hydrogen and oxygen. The third element carbon is obtained from the carbon dioxide found in the air. This gas gets into parenchymatous cells of the leaf through the stomata. Thus from water and the carbonic acid the leaf constructs starch. For this constructive work, *both chlorophyll and light are necessary*. This process of constructive work going on in the leaf is called *photosynthesis*, because it is one of combining simple elements into a compound, and this is possible only in the presence of sunlight. The first visible product of photosynthesis is starch and starch grains are found within the chlorophyll grains. However, in green plants sugar seems to be formed at first and then, it is changed into starch. The cell-sap gets saturated with sugar and this condition will interfere with the work of the protoplasm, if at least a portion of the sugar be not removed or disposed off in some way or other. Further the activity of the chloroplastids will be very much hampered by this concentration of sugar in the parenchyma of the leaf. Part of this sugar is changed into starch and, as starch is insoluble, *there will be no interference with the osmotic activity*.

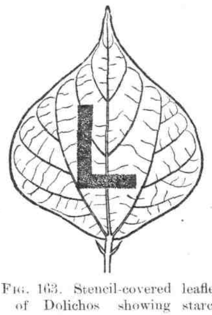


FIG. 163. Stencil-covered leaflet of Dolichos showing starch formation.

It must not be supposed that the process of photosynthesis is a simple one; it is a very complicated process and it probably consists of a series of processes. We have already said that Oxygen and Hydrogen are obtained from water and

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carbon from the carbon dioxide of the atmosphere. Both water and carbon dioxide are very stable compounds, and as such a great deal of energy is required to split them. The energy required for the decomposition of water comes from the protoplasm. But this energy is not enough to separate the carbon from the carbon dioxide. We know that in a leaf no starch is formed in the absence of light. Of course starch cannot be expected to be formed in a leaf, if carbon dioxide is withheld. Since light and green colour are essential for this process we should *infer that the green chloroplasts are* able to obtain energy from the rays of light. Light is *absorbed and it is converted into some form of energy*, probably electric energy. And this energy is used for the *separation of carbon from the carbon dioxide.*

In the leaf carbon dioxide and water are in some way broken up and their elements rearranged so as to form carbohydrates, oxygen being given off. The evolution of oxygen takes place only when the plant is exposed to sunlight. That oxygen is given off when photosynthesis is going on, can very easily be demonstrated. Place in a glass vessel, which is filled with water a few leaves of any aquatic plant, such as Ottelia, Hydrilla, Vallisneria, etc. Invert over the submerged leaves a glass funnel, and then invert over the funnel tube a test tube filled with water. On exposing the whole of the apparatus to sunlight for sometime, bubbles of gas will begin to rise from the cut ends of petioles or branches. After an hour or two a considerable amount of gas will be accumulated in the upper part of the test tube. This gas will make a red-hot splinter burst into flame, and this is the regular test for oxygen. The evolution of oxygen from green plants goes on as long as there is sunlight and carbon dioxide.

The formation of sugar from the simple substances water and carbon dioxide is generally explained as follows by physiologists :—

Carbon dioxide.		Water.		Formaldehyde and Oxygen.		
CO_2	+	H_2O	=	CH_2O	+	O_2

Six times CH_2O is grape sugar and malt sugar is $C_{12}H_{22}O_{11}$.

The sugar formed in the leaf is the starting point for starch. As there is plenty of sugar in the leaf and as the

elements required for the formation of proteids are also there, the synthesis of proteids in the leaf is an easy matter. As a matter of fact proteids are formed in the leaf. But it must not be forgotten that the green colour is not needed for this process. The formation of proteid can take place in any *cell containing protoplasm. The elements needed for the* formation of proteids are Carbon, Hydrogen, Nitrogen, Oxygen, Sulphur and Phosphorus. Sugar contains Carbon, Hydrogen, and Oxygen. Nitrogen, Sulphur and Phosphorus are brought to the leaf in the form of salts. The energy needed for synthesis of proteids comes from the protoplasm. The living substance undergoes oxidation and the energy set free by this process is used up for proteid formation.

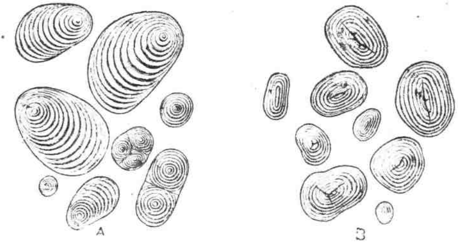


FIG. 164. Starch grains. A., Starch grains of Potato. B., Starch grains of *Dolichos Lablab*. × 500.

In this world the only place where organic matter is formed from simple organic substances is the green leaf. All organic matter existing in this world, however different they may be, wherever they may be found must have been derived or formed from substances manufactured by the leaf. So nature's laboratory for the formation of organic matter is the chloroplast found in green plants. The life of the whole of the organic world is dependent on the process of photosynthesis. If there is no photosynthesis no animal can live. All the stored-up energy of this world are traceable directly or indirectly to this process.

Food of plants.—Plants like animals do work and grow. Both these processes involve some expenditure of energy. And to make good this loss the plant needs food, and the materials used as food are the same in the case of animals and plants. These substances are starch, sugar, oils and proteids. But plants differ from animals in being able to make these substances from simpler substances. Animals on the other hand have to obtain them either from plants or other animals, as they are unable to make organic substances from inorganic substances. Plants in virtue of the possession of the green substance chlorophyll are in a position not only to make food needed for their use, but they are also capable of storing large quantities of food material for future use.

Though plants and animals need the same kind of food for carrying on the various kinds of vital processes, plants take in only inorganic salts such as water and certain gases. The water brought to the leaves by the transpiration current contains several salts, and these constitute the raw products needed for the preparation of the organic substances used as food.

It is obvious that a plant must be supplied with all the elements found in its body. By means of chemical analysis it is possible to determine the constituent substances of plants very accurately. From 50 to 80 per cent. of the weight of a plant body consists of water. After driving away all the water the dry substance may be burnt and analysed. It consists of organic substances containing not much oxygen and so it is combustible, and as the result of combustion we get water and carbonic acid and ash. The chief elements are thus oxygen, carbon and hydrogen. The ash consists of mineral substances contained in the plant. It is obvious that these substances must be in quite different chemical combinations in the ash from those in the protoplasm. The process of combustion brings about this transformation. By a series of very careful analyses of different kinds of plants, it has been determined by chemists that a plant body consists of the elements *Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur* and *Phosphorus*. These elements are absolutely necessary for the growth of the plant, and no growth is possible in the absence of any one of them. Hence these elements are called the *essential elements*.

Taking advantage of the fact that plants absorb everything through the medium of water, plants have been successfully reared in culture solutions. The composition of such solutions may be varied. We may withhold from the plant any element and note the result. By a series of culture experiments it has been determined that in addition to the six elements above mentioned *potassium*, *calcium*, *magnesium* and *iron* must be given to the plant. Although these elements do not actually enter into the composition of the protoplasm, yet they seem to be essential for the various metabolic processes taking place in the plant.

The culture solutions used for water culture experiments are numerous, and some of the important ones are given below :—

Knop's solution—

Calcium nitrate ...	2 grammes.
Potassium nitrate ...	0·5 gramme.
Magnesium sulphate	0·5 ,,
Potassium phosphate	0·5 ,,
Water	1 *or* 2 *litres.*
Iron salt	Very minute quantity.

Sach's solution—

Water	2 litres.
Potassium nitrate ...	2 grammes.
Sodium chloride ...	1 gramme.
Calcium sulphate ...	1 ,,
Magnesium sulphate...	1 ,,
Calcium phosphate ...	1 ,,
Iron salt	Very minute quantity.

Of all the solutions the one known as Von Crone's solution gives the best results. Its composition is as follows :—

Water	1 or 2 litres.
Potassium nitrate ...	1 gramme.
Ferrous phosphate ...	0·5 ,,
Calcium sulphate ...	0·25 ,,
Magnesium sulphate...	0·25 ,,

CHAPTER VIII.

RESPIRATION OF PLANTS.

THE processes concerned in the nutrition of plants and the work of individual organs of a plant have been dealt with in the previous chapter. We have now to turn our attention to the process of respiration of plants, although it has already been referred to in another chapter. This process is a very important one and it is not easy to grasp, at the first presentation, all the facts connected with it. We should also try to learn the part plants play in the economy of nature.

All living beings are continuously at work so long as they are alive. And the performance of vital functions and the maintenance of life is dependent on the continuous supply of oxygen. Should the supply of oxygen be cut off all the activities in an organism will be brought to a standstill and, unless it is supplied within a reasonable time, the plant or animal will lose its vitality.

It is a well known physical law that work, whatever its form and wherever done, involves an expenditure of energy. An engine at work is consuming energy supplied to it by the coal or fuel. When the coal or fuel burns, heat is generated and heat is one form of energy. A plant also is as truly a machine as a steam engine, so long as it is alive. Therefore, the work of a plant also implies a supply of energy. Whence does a plant get energy for doing its work ?

It is a matter of common observation that an animal doing work breathes and that breathing increases, when the work becomes harder. So, we have to conclude that the power of doing work is connected with breathing in some way. Breathing, or respiration, as it is called, consists in taking in oxygen and giving out carbon dioxide and water. Some experiments have already been described by which we learn that plants also respire. A plant, from the moment it begins its life until its death, continues to respire incessantly. When respiration ceases the plant also dies. This intimate relation existing between respiration and the vital functions of the

plant gives us a clue regarding the source of energy which plants need for their work. During respiration considerable quantities of carbon dioxide are given off by the plant and it is obvious that the carbon contained in carbon dioxide should have come from inside the plant. This being so, respiration must lead to loss of weight. Further, this loss has to be made good, if starvation is to be prevented. We know that sugar is formed in plants in the leaves and this is the basic substance utilised for all other organic substances. Therefore this sugar is the source of the respiratory carbon.

All green plants are able to prepare carbohydrates in large quantities, and for the preparation of these substances energy is obtained from sun's rays. The presence of food, or its mere accumulation in a plant body can no more be expected to supply energy than the mere heaping of coals in a steam engine. To set the engine in motion the coal should be ignited. That is to say, the energy lying locked up in coal for untold ages as latent energy has to be released by combustion. Similarly a plant can make use of the energy contained in the food stuff only when it is let loose from the food material. The objects of combustion in an engine and respiration in plants are one and the same. In the engine during combustion heat is generated and it acts on the boiler, piston, etc. Respiration also is combustion, only it is less violent than that going on in an engine. Oxidation taking place within the cell releases energy to be used by the protoplasm.

Even in respiration a certain amount of heat is produced, as in the combustion of coal in an engine. But, it is conducted away as soon as it is produced, because a plant possesses a large extent of surface relatively to its mass. Further, the oxidation taking place in a plant is very much less violent. However in parts of plants where growth is actively going on, there will be a distinct rise in temperature, if care is taken to prevent rapid conduction. The flowers of several Aroideæ sometimes show a rise of several degrees above the temperature of air. Although in the steam engine it is the heat that is used up, in a plant heat is only incidental and it is not used by the plant for its work. It is, not possible to make out the form of the energy that is used by

the plant for its work. We know nothing about the full structural details of the protoplasmic machinery in the cell. The respiratory process, if we take into consideration only the end products, may be expressed as a chemical equation thus :—

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O.$$

In this universe no energy can be created anew or completely destroyed, but they may change their forms. So the energy locked up in the food of plants must have been stored by expenditure of energy. Whence did this energy come ? The carbon dioxide in the air is split inside the cell of a leaf within the chlorophyll grain into carbon and oxygen by the energy supplied by sunlight. The oxygen escapes and the carbon combines with the elements of water and forms a sugar. This is really transformation of the energy of light which is kinetic, into latent energy in sugar. The energy locked up in compounds is latent in the form of unsatisfied chemical affinity, and when the carbon or sugar is made to unite with oxygen then kinetic energy is again given out and this is used by the plant.

Thus we see that the energy stored in the food material as latent energy is let loose, by the process of respiration, as kinetic energy for the use of the plant. An eminent vegetable physiologist describes the food materials of a plant as a kind of storage battery charged by the sun and discharged by respiration.

Both plants and animals respire and so we should expect the carbon dioxide to accumulate in the atmosphere. If this influx of carbon dioxide is not checked, it is obvious that the *surface of our planet will soon cease to have living organisms.* But in nature, in spite of the universal combustion going on in the form of respiration, the atmosphere never becomes foul. *This forces us to the conclusion that there must be* some other process going on in nature which prevents the accumulation of carbon dioxide in the atmosphere. Plants *having chloroplasts take up all the carbon dioxide, and evolve* oxygen, as long as there is sunlight. The air rendered foul by the breathing of plants and animals is thus made pure by green plants.

The process of photosynthesis carried on by green plants is to a certain extent antagonistic to the process of respiration. The former process takes place only during the daytime and in green parts of plants, whereas the latter goes on always, both day and night and in protoplasm, and does not depend upon the green colour. Respiration leads to loss of weight, but photosynthesis brings about an increase in weight; energy is released by the former and it is stored in latent form by the latter. Though the process of photosynthesis takes place only during the daytime, it is at least twenty times more active than the respiratory process.

The part played by the green plants is of the utmost importance in the economy of nature. The main work of a chlorophyll bearing plant is the continual transformation of the energy of sunlight into latent chemical energy. The chloroplastid is an apparatus imbedded in protoplasm for catching the sun's rays. In fact the plant is a machine whose work is to store up large quantities of latent energy, by the absorption of sunlight. Thus we see that the source of energy is the sun. As already pointed out the formation of starch from simple inorganic substances is the only way by which organic matter is formed upon our planet. "Nature does not possess any other laboratory for the formation of organic matter except the leaf, or more strictly, the chloroplast." The energy thus stored up is released by the process of respiration.

CHAPTER IX.

SPECIAL MODES OF NUTRITION.

A great majority of flowering plants are able to manufacture, *during their lifetime, complex organic substances out* of water, some salts and gases obtained from the soil and the atmosphere. All such plants are normal land plants and *all the processes taking place in them and subserving* nutrition are also to be considered as normal. But amongst flowering plants there are a few that show a departure *from the normal* modes of nutrition in certain respects. For example, plants like Viscum, Loranthus, Striga, and Santalum, instead of growing in the soil, attach themselves either to the branches or roots of other plants. And yet all these plants carry on the function of photosynthesis as well, as those plants that grow rooted to the soil. But for water and salts they are dependent on other plants, as they cannot get them from the soil. On account of this partial dependence such plants as these are called *semiparasites*. Because of the change in their habit, semiparasites have their roots modified, so as to suit the altered

FIG. 165. Viscum on a branch of *Pongamia glabra*. 1 and 2 are Viscum plants.

conditions. These modified roots, or *haustoria* are specially adapted to obtain water from the wood of their host plants.

The Viscums and the Loranthuses found growing on the branches of trees, such as the Margosa, the Mango, the Tamarind and Pongamia are typical semi-parasites. There is nothing in the stems and leaves to suggest their parasitic life, but the roots plainly indicate this tendency. Further, the modifications in the root are of such a nature as to enable them to penetrate the bark and become intimately connected with the inner woody tissue of the host plant. Without this intimate connection, these plants cannot absorb water and it would be impossible to secure fixation to the branch of the host plant.

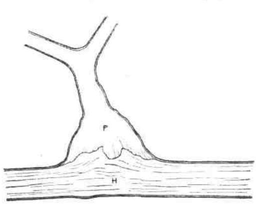


FIG. 166. A section through a haustorium of Viscum showing the fusion of xylem between the host and the parasite. P. parasite Viscum, H. host plant Pongamia.

Viscums usually attach themselves to their host plants in only one place. On the other hand species of Loranthus secure attachment to a number of places by producing numerous haustoria, and, therefore, these are more destructive to their host plants than Viscums. All the species of the family Loranthaceæ are semi-parasites and they invariably grow on the branches of the shoot-systems of trees. (See fig. 79 for Loranthus parasitic on a branch of *Albizzia amara*.)

We have next to consider flowering parasites growing on the roots of the host plants. One of the most common and widely spread plant of this kind is *Striga lutea*. It flourishes in fields, fallow or cultivated, and it grows from the roots of grasses, cereal plants or weeds. Striga attaches itself to the root of the host in only one place, but Santalum, Ximenia and Cansjera produce a number of haustoria and secure attachment in many places on the root system of the host plant.

The semi-parasites so far mentioned have abandoned the usual mode of life of a green flowering plant, only in the manner of obtaining water and salts. So the advance in the direction of parasitism is not very great. Some species of Striga, however, show a little more advance in this direction. For instance, *Striga orobanchoides*, which is usually found parasitic on Lepidagathis, Opuntia or Euphorbia is dark purple in colour and there is not much of green colour in it. Besides this, the leaves are reduced and scale-like. (See fig. 78.) So this plant cannot be expected to manufacture carbohydrates and, therefore, it must obtain them from the host plant. Other striking examples of flowering parasites that are devoid of chlorophyll and are parasitic on the roots or stems of plants are the *Orobanches*, *Cuscutas* and Cassytha. Amongst the Orobanches, *O. nicotianæ*, which is so destructive to the tobacco crop is widely distributed and well known. The tangled masses of yellow or greenish yellow threads found on trees such as Eugenia, Acacia and Buchanania are all of the species *Cassytha filiformis*. *Cuscuta chinensis* generally attacks herbs such as *Ipomœa biloba*, *Launæa pinnatifida*, etc. The threads twine round the stems and cling on to the support by means of numerous haustoria produced

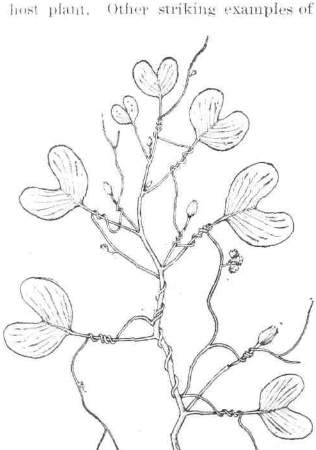


FIG. 167. Cuscuta parasitic on *Ipomœa biloba*.

at short-distances. Obviously these cannot do the work of photosynthesis.

In all flowering parasites that do not produce the chlorophyll, the vegetative part of the plant should be expected to be very much reduced. The most conspicuous part of the plant body in all these plants is the inflorescence. The wonderful root parasite Rafflesia, already mentioned in a previous chapter, is nothing but a huge flower measuring about a yard across.

On account of their parasitic habits, these plants are at a great disadvantage in the matter of dispersion of seeds and the securing of proper places for germination, compared with the ordinary land plants. In spite of this, we find all these parasites flourishing well all over the country. Very often these become serious pests: for instance, in many a place the plant *Striga lutea* grows so luxuriantly, as to be the despair of a farmer. We meet with trees full of Viscums or Loranthus all over the country. Therefore, we have to conclude that these plants have some special features to enable the seeds to find suitable places for their germination. All parasites should be able to find out their appropriate hosts, when they are young. Unless the seeds are close to their host plants, the seedlings run the risk of not finding their host plant. This risk is minimised in all parasites by their ability to produce seeds in large numbers. For example, a single Striga plant produces a mass of fine seeds numbering over sixty thousand. Even in Viscum and Loranthus seed production is fairly extensive, though not so profuse as in Striga or Orobanche. But the fruits are sticky and edible. So birds peck these fruits and as the seeds stick on to their beaks they get rid of them, by transferring them to the twigs or branches of trees. This is what is required for the seeds to germinate. In the case of parasites producing fine seeds in large numbers, the seeds do not germinate except under some special circumstances. Nearness to the host plant seems to be an essential condition for germination. The exact manner in which the host influences the seed is unknown. It is this striking peculiarity of the seed that enables plants like Striga and Orobanche to become serious pests. The seeds are hardy and remain dormant, until they come in contact with appropriate hosts.

The group of plants called fungi are entirely lacking in chlorophyll and, therefore, they have to obtain everything they want either from other animals or plants. Many of the fungi are parasites and they are responsible for most of the deadly diseases of cultivated plants. The rust, the smut and the mildew which destroy crops wholesale are all fungi. Several fungi obtain what they want from the debris of dead animals and plants and they are called *saprophytes*.

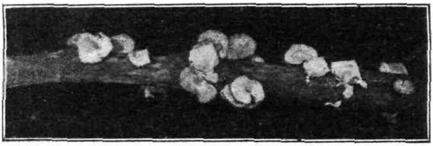


FIG. 168. A Saprophytic fungus.

In many ways the fungi are one of the most remarkable groups of plants. Though the vegetative parts of fungi are very simple, their power of adaptation to varying conditions and the way they affect their hosts are things to be wondered at. Some fungi become associated with the roots of certain plants and such roots are called *mycorrhiza*. These roots are devoid of root-hairs and, instead, have a fine covering of fungal hyphæ. The fungus undoubtedly gets carbohydrates from the root and the work of absorbing water is done by the fungus.

There is also a very close association between a fungus and an alga (a lowly organised plant with chlorophyll) in what are called lichens. The alga prepares the carbohydrate material for its own use as well as for the use of the fungus and the fungus absorbs water and salts. (See fig. 170.)

There is yet one more method of nutrition observable in some plants to which we should now turn our attention. Plants usually obtain the nitrogenous substances they require, by the usual method of proteid assimilation. But some plants do not seem to be able to get enough of these substances and so they have adopted a novel method of

supplementing their supply. By special adaptations these plants are able to catch small insects and make use of the nitrogenous stuff contained in them. As examples of such plants we may mention the species of Droseras and Utricularias flourishing in this Presidency. In swampy situations, all over

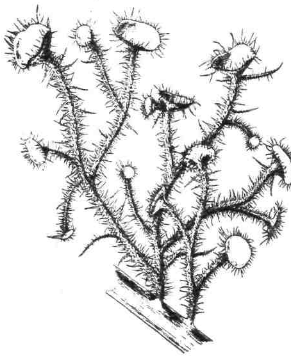


FIG. 169. Lichen *(Usnea barbata)*.

the Presidency we meet with a tiny plant with small rosettes of leaves appressed to the ground. From amidst the leaves rises, the inflorescence, which is a false raceme with white flowers. This is *Drosera Burmanni*. The leaves are somewhat rounded with a short narrow stalk. The whole upper surface of the blade is beset with bristle-like hairs ending in glandular tips. These hairs are reddish and are always secreting at their free ends a clear, sticky liquid. When an insect happens to become entangled amidst these glandular hairs, all the hairs curve inward and the sticky juice is secreted in abundance and the prey is ultimately digested. In another species *D. indica* the leaves are linear and in other respects it is the same as *D. Burmanni*. (See figs. 155 and 156.)

In Utricularia we have another set of plants that capture small animals and make use of them as food. These plants flourish in marshes and in the edges of ponds and in wet

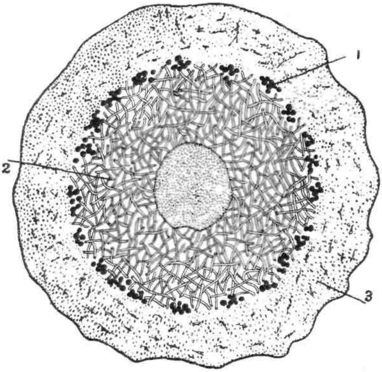


FIG. 170. A transverse section through the filament of Usnea, highly magnified. 1, *algal cells*; 2, *fungal hypha*; 3, compact *fungal hypha*

places generally. The leaves are modified into special bladder-like structures with trap-doors to capture small insects as prey. (See fig. 158.) The most common species are *U. Wallichiana* and *U. reticulata*.

Lastly we have the group bacteria to consider. Some of them are parasites and others saprophytes. The process of decay going on always in this world is hastened by some bacteria and fungi.

CHAPTER X.

GROWTH AND MOVEMENT IN PLANTS.

LARGE quantities of food material are produced by a green plant. But it utilises for its growth only a small part of it. The remaining portion is stored in places such as roots, stems, fruits and seeds. The manufacture of organic substances is to help the growth of the plant, and growth means increase of organs in size and number. Growth and formation of food may go on for any *length of time under favourable* conditions. Once a plant starts life, it may go on living for any length of time, so that the same individual continues to live. Consider the case of such a tree as the Banyan which is capable of growing for a long time unceasingly and covering many acres of land by gradual extension, if left undisturbed. It produces adventitious roots from branches, and these get into the soil and support the branches and also absorb water containing salts. As examples of trees thus extending we may mention two Banyan trees in this Presidency, one in the neighbourhood of Madura town and the other near the village Jakkeri, in Hosūr taluk.

A plant assimilates the food it prepares and transforms it into cells, and formation of new cells leads to the process of growth. The processes of nutrition and growth are independent. They do not take place at the same time, and in the same place. *Growth is active in the younger parts of plants*, and the fully developed organs alone are concerned in the work of nutrition. In plants growth is localised and it can go on unchecked so long as conditions are favourable. But in animals it is not localised and it ceases after a certain stage.

By growth we mean increase in bulk, and it must not be forgotten that it is not necessarily due to addition of new matter. For instance, during germination the growing seedling will show loss of material, instead of gain in weight. Increase of bulk in the case of growth is brought about by the addition of new cells and their subsequent expansion,

Growth really consists of three distinct processes, viz., the formation of cells by cell division, elongation of cells and their differentiation. The division of cells takes place at the *extreme tip, and the other two processes take place in the region lying behind the actual tip.* It must not be supposed that these three regions are quite distinct, one region passes into the other insensibly. At the actual tip the formation of *cells is the most prominent feature, and in the part behind it,* elongation is the chief feature, though differentiation may be going on in certain cells.

All the cells constituting the tip of the growing point are small and meristematic. Further, the protoplasm in these cells is very compact and fills the cell completely. As new cells constantly arise, those already formed begin to change in size, shape and character. Gradually the protoplasm in these cells begins to absorb water and the cells then become turgid. The extra amount of water absorbed must necessarily put the cell wall on the stretch. The protoplasm inside the cell, being always active adds to the cell-wall so that it retains permanently the size it gets under pressure. Once again the cell-wall will be stretched and there will be addition of material leading to the further growth of the cell-wall. This process of tension and growth will be going on until the cells attain their permanent form. As soon as this takes place differentiation of cells commences.

By closely watching the growth of the roots and the shoots of seedlings, we may ascertain that growth in length is confined to the part behind the actual tip in the growing points. To facilitate the observation, marks may be made at equal distances with *water-proof Indian ink on the growing* portions of the root or the shoot. Marks made on the part behind the growing tip alone get separated.

Movements in plants.—A plant has different kinds of work to do. If it is to perform all its functions properly, it must possess not only the power of placing all its organs in the position most appropriate for the due performance of their functions, but they should also have the power of responding in a suitable manner, when changes occur in external conditions. All the organs must be arranged to their best advantage. For instance, the foliage leaves must be so held as

to enable all the leaves to obtain sufficient light and the roots have to get into the soil and there branch in an adequate manner.

The factors, influencing the organs of a plant are gravity, moisture and light. The main root of a plant goes vertically downward in response to the stimulus of gravity. For the tap-root this is the position of rest or equilibrium, and the same stimulus has a different directive influence on the lateral roots ; these take a horizontal course. The shoot also is subjected to the influence of gravity, but its position of rest is different from that of the root. It goes straight up against gravitation. Any disturbance in the equilibrium in the root, or in the shoot causes the part disturbed to make a curvature which will enable the member to assume the position of rest.

Movements exhibited by plants in response to stimuli are due to the property of irritability possessed by plants. The protoplasm is able to respond to stimuli of different sorts, and irritability is one of the fundamental properties of the protoplasm.

The root has the power of responding to both moisture and gravity. When a root is disturbed by any change in its position of rest, it readily responds by means of growth curvatures, and the movements causing the curvatures are called *trophic movements*. For instance, a seedling having a well developed tap-root when placed in a horizontal position will show a curvature a little above the growing tip and the root-tip will assume the vertical direction. This movement of the root in response to the influence of gravity is called *positive geotropism*. As growth in length chiefly takes place just behind the root-tip, the growth curvature is seen in this region. It should also be remembered that the root-tip alone is sensitive to the stimulus of gravity. The tap-root of a seedling is not affected by gravity when the actual growing tip is cut off. However, when a new growing point is formed, the root responds. From this it is clear that the root-tip alone is sensitive. The shoot also under similar circumstances responds to the stimulus of gravity by means of a growth curvature just behind the actual growing tip. But the direction of the curvature in this case is quite opposite to that of the root, and hence the shoot is said to be *negatively*

geotropic. The reason for this difference in behaviour, although the stimulus is the same, is the difference in *structure between these two organs*.

The fact that the root and the stem are made to grow as they do by the influence of gravity may be demonstrated by means of a special apparatus, called the Klinostat. The apparatus is only a clock-work arrangement which rotates an axis bearing a plate at its free end. The axis can be made to be horizontal in position. In this position of the axis the plate must necessarily rotate in the vertical direction. If we fix to this rotating plate, seedlings in *different directions*, no curvatures are seen either in the root or the shoot. This is because the seedling is exposed on all sides equally to the *influence of gravity*. *So there is no curvature*. This method is adopted as it is impossible otherwise to prevent the action of gravitation.

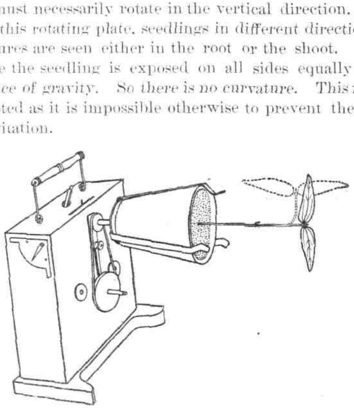


FIG. 171. Klinostat. The dotted line denotes the position the leaves and the axis at the top would occupy when the Klinostat is not set going.

The response of the root to the stimulus of moisture is called *hydrotropism*. One may probably be led to wonder as to why the root should be influenced in this manner by gravity and moisture. If we remember the functions that a root has to perform, it becomes obvious that it is necessary for the root to be so affected by these two factors. The great need of the root-system is to explore the soil thoroughly and

to come in contact with as much soil as possible, in order to do its work efficiently.

The tap-root has generally a tendency to grow vertically downwards. But it will not do so under all circumstances. Sometimes, for the sake of moisture, it will move against the force of gravity. If in a large seedling-pan filled with saw-dust or sand, we place in the centre a flower-pot filled with water and plant around it outside seeds and allow them to sprout and grow into seedlings, we shall find all the roots turned towards the pot containing water. In the case of epiphytes the aerial roots sometimes grow straight up for the sake of attaching themselves to branches lying above them.

As green plants require light for doing their work, we should expect them to respond to the stimulus of light also. When a plant is placed near a window, the shoot invariably curves over towards it because of the one-sided illumination. When a plant fixed to the plate of a Klinostat in motion, is placed near a window, the stem does not curve towards the window, but grows erect. In this case the plant receives equal illumination on all sides. A *Dolichos Lablab* seedling placed near a window showed the curvature within twenty minutes. Plants growing in open places grow straight, for they are equally illuminated on all sides. In a shoot bending towards light, the axis lies in the direction of the light rays, whereas the leaves are either at right angles, or oblique. This conclusively proves the fact, that the same stimulus does not necessarily produce the same kind of response in all the organs of a plant. As a matter of fact, the response is dependent upon the character of the organs concerned, as well as upon the nature of the stimulus. Aerial roots and tendrils of certain plants turn away from light.

In the case of all curvatures the actual bending takes place only in the region of maximum elongation, but the power of perception belongs to the younger parts above it.

We should not omit the movements exhibited by protoplasm within the cells. In the epidermal hairs of Cucurbitaceous plants the protoplasm inside the cells shows a kind of movement which is called *circulation*. The protoplasm within the epidermal hair-cell consists of a layer adhering to the cell-wall and a number of slender protoplasmic threads

and they are in different directions. There is another kind of movement in which the protoplasm moves along the cell-wall in one direction only in a cell, carrying with it the nucleus and the chlorophyll grains. This movement is called *rotation*. The direction of movement will be different in different cells, but inside the same cell the movement will be in one direction only. In one cell the motion may be from right to left and in a second cell it may be from left to right and so on.

CHAPTER XI.

INFLORESCENCE.

WE have already examined as types the Tribulus and Gynandropsis plants. In the former the flowers are borne singly in the axils. Judging from the position, we have to conclude that the flower is really a branch bearing floral leaves, instead of foliage leaves. In *Gynandropsis pentaphylla* the flowers spring from the axils of leaves, but they are all gathered together towards the extremities of branches. The leaves from whose axils flowers grow out do not differ very much from the ordinary leaves in this plant, except that they are small. But leaves thus associated with flowers are generally small and differ very much from the foliage leaves. Such leaves are termed *bracts*. The flower bearing axis in Gynandropsis grows steadily upwards producing flowers one after another in regular succession; and so the oldest flowers are below, i.e., further away from the apex of the axis and the order of the opening of the flowers is from the base upward towards the apex (*acropetal succession*).

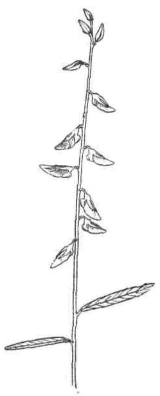


FIG. 172. Raceme of Crotalaria.

A collection of flowers on an axis is called an *inflorescence*. There is considerable amount of variation in the matter of the arrangement of flowers, and so we have different kinds of inflorescence. An inflorescence similar to that of Gynandropsis, i.e., one in which a number of stalked flowers are borne by an elongated axis in acropetal succession, is called a *raceme*. There are many plants having this kind of inflorescence, and as examples we may mention those of Crotalaria, *Sesbania ægyptiaca*, Cleome and Tephrosias. In all these plants the flower-stalks are, more or less, of the same length. In the terminal younger part of the inflorescence of Gynandropsis the pedicels of the lower flowers are longer than those above and as a consequence all the flowers are on the same level. This kind of inflorescence is called a *corymb*. (A cymose inflorescence also is sometimes corymbose.)

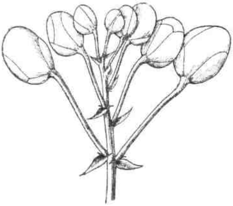


FIG. 173. Corymb of Cassia.

Examples of corymbs may be seen in Cassia, Cæsalpinia and Ixora.

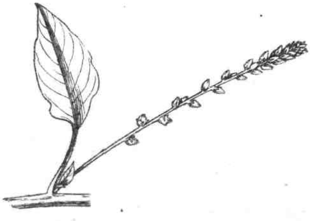


FIG. 174. Spike of Digera.

Flowers are not always stalked. They may be sessile on the axis as in the inflorescence of *Achyranthes aspera*. Com-

pared with the raceme this differs from it in only one respect, viz., the absence of pedicels. Such inflorescences as these are called *spikes*. As further examples of spikes we may mention the inflorescences of Amarantus, Digera and Celosia. Sometimes the axis of the spike becomes fleshy and a large sheath or bract also becomes associated with it, as in the case of the inflorescence of Colocasia or Amorphophallus. Then the inflorescence is termed *spadix*, the sheath being called a *spathe*.

FIG. 175. Spadix and spathe of an Aroid.

Very often the stalked flowers, instead of springing from the axis at different heights, arise from the summit of the main axis, and this is called an *umbel*. The inflorescences in Onion, Coriander, Tylophora and Pentatropis are all umbels. If we imagine the flowers of an umbel to be sessile, instead of being stalked, we have an inflorescence termed a *head* or *capitulum*. The summit of the peduncle becomes enlarged, in this case, so as to afford room for the sessile flowers. The so-called flowers of the Sunflower plant, of Tridax and of Vernonia are all heads.

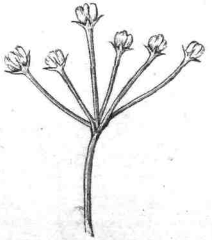


FIG. 176. Simple Umbel of an Asclepiad.

The raceme, spike, umbel and head have the flowers in the same succession. The oldest flower is at the base and the youngest is at the top of the axis. Further, the axis is a

FIG. 177. Compound Umbel.

monopode. So these may be considered as forming a type of inflorescence, and the type is called *racemose* or *botryose*.

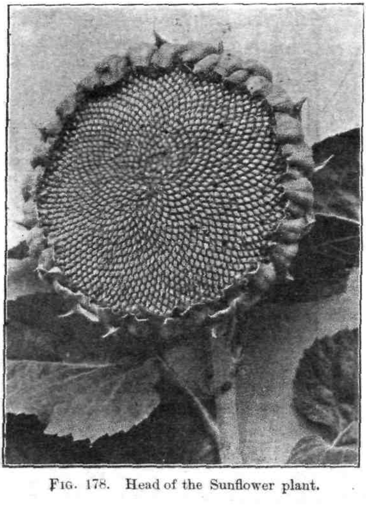


FIG. 178. Head of the Sunflower plant.

It is also called *centripetal* because the order of blossoming of the flowers is from the circumference of a circle to its centre ; another term sometimes used is *indefinite*.

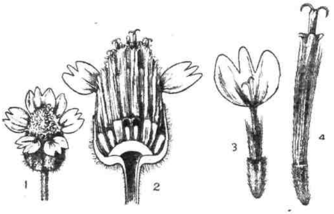


FIG. 179. Flower head of Tridax. 1, entire head ; 2, head cut vertically ; 3, ligulate flower ; 4, tubular flower.

In some plants the main axis terminates in a flower which is the first to open. Lateral branches arise later from below and they also end in flowers. The inflorescence in the ordinary Jasmine plant is of this kind. It consists of an old

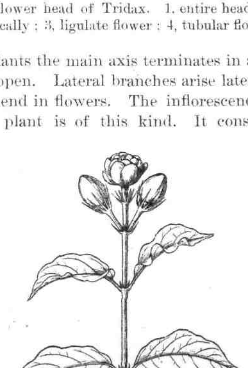


FIG. 180. A simple cyme of the Jasmine plant.

flower in the centre and two young flowers laterally, one on each side. This kind of inflorescence is quite distinct from the botryose type and so it is called *cymose*. As the order of

flowering in this type is from the apex to the base *(basipetal)*, the inflorescence is described as *centrifugal*. It is also called *definite*.

In the cymose type of inflorescence also there are certain variations deserving notice. The three flowers forming an inflorescence in Jasmine may be termed a simple cyme. A simple cyme of this sort becomes modified in many plants. The lateral branches, in their turn, give rise to lateral flowers, one on each side. Then, instead of a simple cyme, we get an older flower with two simple cymes on the two sides. Such inflorescences as these are met with in several species of Ipomœa, Clerodendron, etc. This kind of increase is in some cases repeated indefinitely, as in the case of Nerium and Wrightia. If the development of the lateral branches is regular the inflorescence is called a *dichasium*.

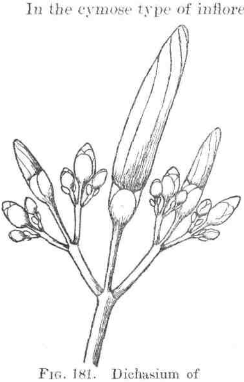


FIG. 181. Dichasium of *Ipomœa carnea*.

Irregularity, in the development of the lateral branches in the cymose type of inflorescence, is not uncommon. Instead of having lateral flowers on both the sides, the central flower may have only one, on one of its sides. If the suppression of the lateral flower is confined regularly to the same side, as in some Solanums, we get what is called a *helicoid cyme*. If, on the other hand, the suppression takes place alternately first on the right side and then on the left regularly, as is seen in the Heliotropiums,

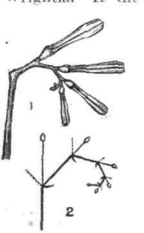


FIG. 182. Helicoid cyme. 1, helicoid cyme of Hamelia ; 2, diagram showing suppression on the same side.

the cyme is termed *scorpioid*. In both these varieties the axis becomes straight later, though in the young stage it is coiled at the free end, and it is a sympode. The helicoid cyme may be mistaken for a raceme with flowers all on one side. But as the axis is really a sympode the arrangement of the bracts will be quite different. In the case of the helicoid cyme the bracts when present will be opposite to the flower, and in the case of the scorpioid cymes there will be two rows of bracts, if present.

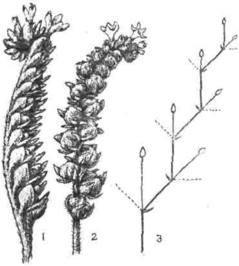


FIG. 183. Scorpioid cyme of *Heliotropium ovalifolium*. 1, side and 2, front view ; 3, diagram to show the alternate suppression of lateral flowers.

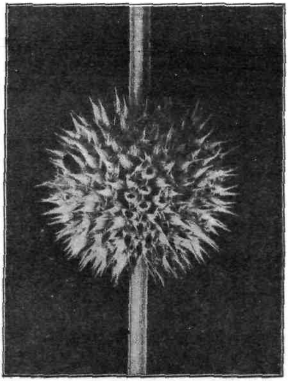


FIG. 184. Verticillaster of *Leonotis nepetæfolia*. (Slightly reduced.)

Sometimes two cymes spring at the nodes opposite to one another as in Ocimum and some other genera of the same family. In some cases, as in Leucas and Leonotis the cymes become condensed and overlap the axis and look like a whorl of flowers : so this is called a *false whorl or a verticillaster.*

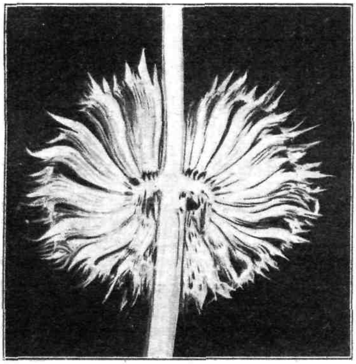


FIG. 185. Verticillaster of *Leonotis nepetæfolia* cut through to show the cymose nature of the inflorescence.

The main kinds of inflorescences and their modifications may be tabulated as follows :—

A. The Racemose type.—In this type the rachis gives rise to flowers in acropetal succession, i.e., the young flowers are at the top and the old ones at the base of the axis. This is also called *centripetal* or *indefinite.*

(1) *Raceme*—pedicelled flowers borne by an elongated axis from the base upwards in acropetal succession.

(2) *Corymb*—A raceme in which the pedicels of the lower flowers are longer than those of the upper.

(3) *Umbel*—pedicelled flowers all springing from the top of the axis.

(4) *Spike*—sessile flowers borne by an elongated axis from base upward.

(5) *Capitulum*—sessile flowers on the summit of the main axis which becomes enlarged.

All these inflorescences are of the simple type. We have also compound forms.

(1) *Compound raceme.*—The main axis, instead of bearing stalked flowers, has racemes.

(2) *Compound umbel.*—The peduncle bears umbels instead of single flowers.

(3) *Compound spikes.*—Simple spikes arranged on an elongated axis.

(4) *Panicle.*—Any inflorescence with a loosely branched appearance, whether the branching be racemose or cymose or both.

B. The Cymose type.—In this type the primary axis or rachis ends in a flower and then produces immediately below the first flower lateral axes either terminating in a flower or behaving like the main one by further branching.

(1) *Simple cyme.*—The axis bears three flowers, the central one being the oldest.

(2) *Dichasium.*—The axis terminates in a flower and then produces a pair of lateral branches bearing cymes that are simple or they may also become branched further by repeated divisions.

(3) *Monochasium.*—An elongated sympodial axis bearing flowers, the bracts being opposite the flowers. There are two varieties of monochasium.

(*a*) *Helicoid.*—The lateral branches develop on only one side in a regular manner, and the other one being regularly suppressed on the other side.

(*b*) *Scorpioid.*—The suppression of the lateral branch is alternate, i.e., the right one is suppressed and then the left and again the right and so on.

(4) *Verticillaster.*—Axillary cymes very much congested and surrounding the stem.

CHAPTER XII.

THE FLOWER.

A flower is a short shoot appearing only periodically on a plant with longer or shorter intervals. In plants we find leaves and leafy shoots always, but not flowers. This is so on account of the difference in their function. Leaves and other vegetative organs are concerned in the work of nutrition, a process going on continuously. On the other hand, flowers are the organs intended for the propagation of plants, through the seeds : and propagation is not one of the processes going on continuously in a plant. So we do not find flowers always. Large quantities of food material are needed for the formation of flowers and this is why a young plant does not produce flowers. A period of vegetative activity must necessarily precede the formation of flowers, otherwise large accumulations of food material are not possible. In corms and bulbs large amount of food is stored and therefore they give rise to flowers when planted.

From a study of the *Tribulus terrestris* flower we have learnt that a flower consists essentially of an axis carrying sepals, petals, stamens and the pistil. The first two, sepals and petals, are only accessory organs forming the perianth of the flower. The remaining two sets of organs form the essential organs of the flower. This flower is a complete one because it has all the four sets of the floral organs. Both the essential organs of the flower exist together and so the flower is *bisexual* or *hermaphrodite*.

Let us now look at the arrangement and the insertion of the various parts in the flower. All the parts are attached to the free-end of the flower-stalk in a definite order. The apex of the stalk, or the *receptacle*, as it is called, is surmounted by the pistil and the other whorls are below this. The pistil is therefore said to be superior, and the other parts inferior.

The parts of the outermost whorl or sepals alternate with the petals. There are two whorls of stamens, the inner being

opposed to the petals and the outer to the sepals. The carpels in the innermost whorl alternate with the second or the inner whorl of stamens. There are five protuberances in this flower, connected with the shorter stamens. These are called glands.

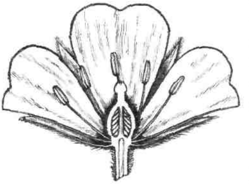


FIG. 186. A longitudinal section of a flower of Tribulus showing the attachment of the parts

The Tribulus flower possesses five whorls and each of these consists of five members. Further, the flower can be cut into two symmetrical halves *through any plane*. So it is a *typical regular, symmetrical flower*.

A *transverse section through a young bud* will reveal the general arrangement of the various parts. It is usual to

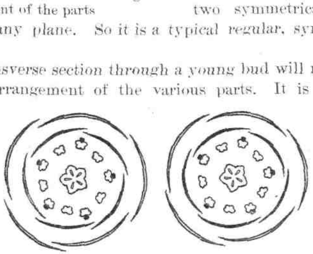


FIG. 187. Floral diagram of Tribulus.

represent such sections diagramatically, and they are called floral diagrams. For showing in a clear manner the positions of the parts, it is a convenient method. Circles corresponding in number to the whorls are drawn concentrically and on them the position, as well as the union of the parts of each whorl, are marked. The position of the main axis bearing the flower and that of the bract are also usually represented in the diagram. The floral diagram is represented in fig. 187. Out of the five sepals, two have both their margins outside, two have them inside and one has a margin inside and the other outside. One petal has both the margins outside, another has both its margins inside, and the remaining three

petals have one margin in and the other out. In some flowers petals are contorted.

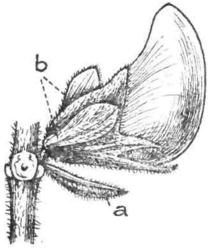


FIG. 188. Bract and bracteoles in the flower of *Dolichos Lablab* a, bract, and b, bracteoles.

Flowers that are solitary usually arise from the axils of leaves. But in the case of flowers that are clustered together so as to form inflorescences, the individual flowers spring from the axils of very small scale-like structures and not from the axils of foliage leaves. These small structures are bracts. There are also instances in which the bracts are wanting, as in the case of Mustard and Cleome. Very often, we meet with plants whose flowers bear, in addition to the bract, two small additional scale-like structures. These are called *bracteoles*. The flowers of *Dolichos Lablab* and *Clitoria Ternatea* have both bracts and bracteoles. We have also instances of flowers having more than two bracteoles, in the flowers of Hibiscus, Pavonia and Cotton. There is yet one more variation in the bract already referred to in the last chapter and this should not be passed by. The whole of the inflorescence in certain Aroids and palms is enclosed completely, by a large sheath and it is termed a *spathe*. It is not uncommon to have more than one spathe in the inflorescence, for instance there are many spathes in the spadices of Musa.

We find endless variations in the structure of flowers and so it is necessary to examine the flowers of a few more plants. We may study the flowers of *Dolichos Lablab*, Crotalaria, any Hibiscus, Ipomœa, *Ruellia prostrata*, *Allium Cepa*, *Crinum asiaticum* and *Aristolochia bracteata* with advantage.

The flowers of *Dolichos Lablab* are clustered together so as to form a compound raceme. The flower-stalks of the individual flowers (pedicels) spring from the axils of small bracts and there are also two bracteoles, one on each side of the calyx. The outermost whorl of the flower the calyx, is in

the form of a cup, but five divisions may be made out in it, showing that it consists of five sepals; in such cases as these,

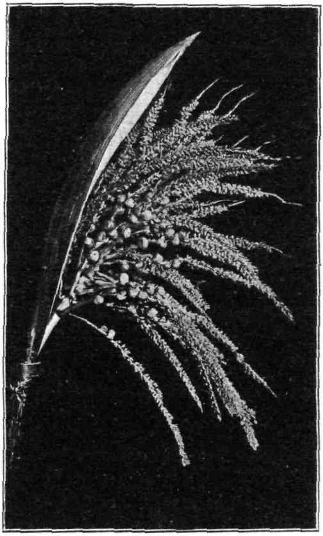


FIG. 189. A spathe and spadix of the Coconut palm.

the calyx is described as *gamo* or *mono-sepalous*. Of petals there are five, and they are not all alike; one petal is larger than the others and it is the outermost in the bud. In an open flower this petal stands upright and is generally very conspicuous, and it is called the *standard*. On the sides of the standard and below are two petals and these are called *alæ* or *wings*. Next to these come two narrow petals bent in the middle and cohering so as to resemble a boat, the *keel petals*. Within the keel petals lie the stamens, ten in

number. One stamen alone remains free and the remaining nine are united together by their filaments so as to form a tube slit on one side. Stamens thus united into two bundles are described as *diadelphous*. The anthers are all uniform. The pistil consists of an ovary and a style bent in the middle so as to correspond with the bending of the keel petals.

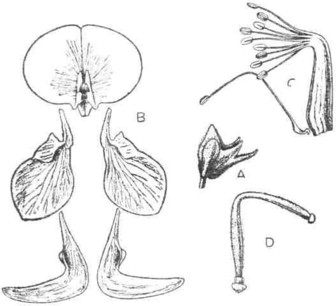


Fig. 190. The floral parts of *Dolichos Lablab*.
A, calyx ; B, petals ; C, stamens ; D, pistil.

The flowers of Crotalaria resemble those of *Dolichos Lablab* in all essential respects. The stamens are in this case in one bundle *(monadelphous)* and the anthers are of two kinds, five elongated and five rounded and short. When the stamens are of two kinds, as in this case they are said to be ***dimorphic***.

Of the various species of Hibiscus the commoner ones, such as, *Hibiscus esculentus*, *H. vitifolius*, *H. cannabinus* and *H. micranthus* may be examined. In *Hibiscus esculentus* the flowers are solitary and axillary. There are a number of bracteoles forming an epicalyx. The calyx is tubular and it opens on one side to allow the petals to come out. There are five petals free except at the very base where they are attached to the staminal column. The stamens form a

tube, i.e., they are monadelphous. All the anthers are borne by short threads disposed along the outside of the tube. An anther usually consists of two lobes, but in this flower it has only one lobe. Within the staminal tube lies the pistil, which consists of a dilated portion, the ovary, a thin thread-like part, the style, terminating in five branches bearing the stigmas.

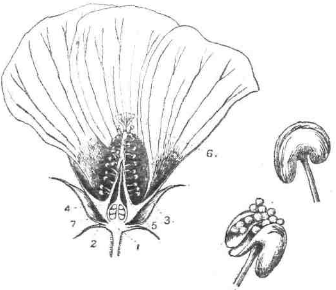


FIG. 191. The floral parts of *Hibiscus vitifolius*. - 1, receptacle ; 2, bracteole ; 3, calyx ; 4, base of petal ; 5, staminal tube ; 6, style branches bearing stigmas. Two anthers, one closed and the other open, are also shown

The flowers of *Hibiscus vitifolius* and *H. cannabinus* are similar to those of *H. esculentus* in all essential respects, but the bracteoles and the calyx are different. The flowers of *H. micranthus* are rather small and the petals are white, whereas those of the species mentioned above are yellow.

The flowers of Cassia are collected together in simple or compound corymbs, and the flowers are bracteate. The sepals and petals are both free and they are very often of the same colour, and the sepals are then said to be *petaloid*. Further, the sepals vary in size in the same flower in several species of Cassia. Stamens are ten and are not all alike ; some are long with well formed anthers and others short with imperfect anthers. The anthers open by means of pores

at the apex. The pistil is like that of *Dolichos Lablab* in essential points.

The flowers of Ipomœa are different from those already described in this chapter. A flower-stalk terminates in a flower, or there may be three flowers borne by the peduncle and then, the middle flower is invariably the oldest. So the

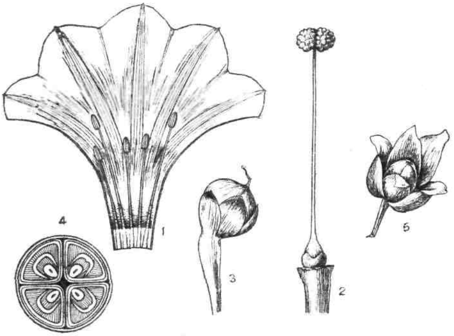


FIG. 192. The floral parts of Ipomœa. 1. corolla laid open with epipetalous stamens : 2. the pistil : 3. young fruit : 4. transverse section of a young fruit ; 5. capsule with persistent quincuncially arranged sepals.

inflorescence is a cyme. In some species it is a dichotomous cyme. The sepals are generally free and their folding is of a particular type called *quincuncial*. Of the five sepals, two are completely outside, two inside and one partly inside and partly outside. The corolla is in one piece and hence called *monopetalous*. It is tubular, funnel-shaped or bell-shaped according to the species. Five lobes can be made out in the corolla. From inside the tube five stamens arise, and so they are said to be *epipetalous*. The pistil consists of an ovary and a thin style terminating in a stigma of two globular bodies. Within the ovary there may be two cells or four.

The flowers of *Ruellia prostrata* are axillary and solitary. The calyx consists of five free sepals and the corolla is tubular and funnel-shaped. There are only four epipetalous stamens, two long and two short. The ovary is two-celled, the style thin and the stigma bifid.

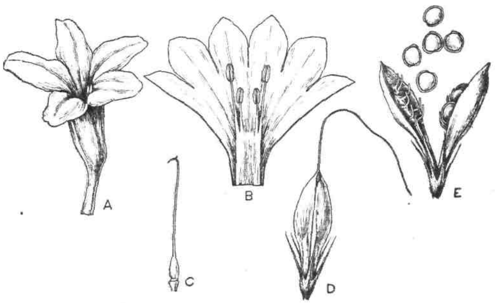


FIG. 193. The flower of Ruellia and its parts. A, corolla ; B, corolla laid open with didynamous epipetalous stamens ; C, pistil ; D, capsule ; E, capsule bursting and hurling the seeds.

The flowers so far dealt with are regular and complete ones. The flowers of Achyranthes and Aristolochia are not so. In both, there is only one whorl of perianth, and it is the calyx. The ovary in Aristolochia is inferior and, in Achyranthes, it is superior. The stamens of Achyranthes are five and they alternate with five scale-like structures, called *staminodes*. In Aristolochia the stamens are reduced to their anthers without filaments and they are sunk within a shortened style. The style is very much abbreviated and it is surmounted by a six-lobed stigma. There are six anthers.

There are many plants in which the flowers are *unisexual*, instead of being *bisexual*. The flowers of Gourds and Cucumber plants are unisexual. In *Cephalandra indica* the flowers in a plant are all either *staminate* (male), or *pistillate* (female). On the same plant we never find both the kinds. So the plant is either a male plant or a female one.

In such cases as these, the flowers or plants are said to be *diœcious*. If both staminate and pistillate flowers are found

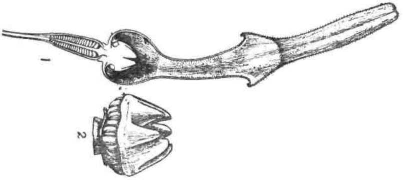


FIG. 194. The flower of *Aristolochia bracteata*. 1. longitudinal section ; 2. stamens and the style.

on the same plant, as in Cucurbita, Ricinus, Cocos and Acalypha, they are said to be *monœcious*. When bisexual as well as unisexual flowers occur on the same plant they are

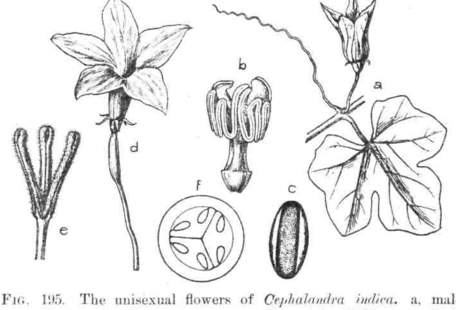


FIG. 195. The unisexual flowers of *Cephalandra indica*. a, male flower ; b, the stamens ; c, pollen grain highly magnified, d, female flower ; e, style branches ; f, transverse section of a young fruit.

polygamous. As examples of plants with polygamous flowers we may mention *Carica papaya*, *Cratæva religiosa* and sometimes *Amarantus spinosus*.

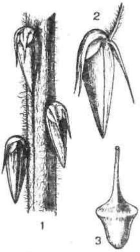


FIG. 196. Flowers of *Achyranthes aspera*. 1, flowers on the axis; 2, detached flower with bract and bracteoles; 3, pistil.

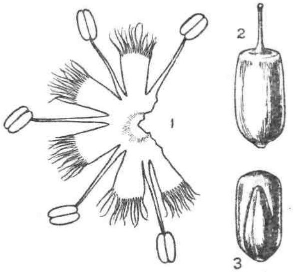


FIG. 197. The floral parts of *Achyranthes aspera*. 1, stamens with staminodes; 2, fruit; 3, seed.

Before dealing with the monocotyledonous flowers, we

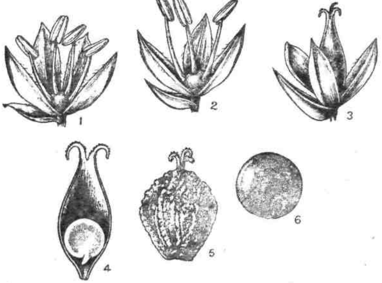


FIG. 198. The floral parts of *Amarantus viridis*. 1, male flower with four perianth lobes; 2, male flower with three perianth lobes; 3, female flower; 4, ovary; 5, fruit; 6, seed.

shall do well to refer to one or more plants having incomplete

flowers. In the very widely distributed *Amarantus viridis* the perianth is single and even this is liable to variation. In most of the male flowers there are three perianth segments, in some four and in rare instances even five. The stamens also vary in number from three to five. In all the female flowers, we find only three perianth segments.

We shall now consider the structure of the flowers of the two monocotyledonous plants *Allium Cepa* and *Crinum asiaticum*.

The flower of Allium or Onion has two whorls of perianth, the calyx and the corolla, both of them being white.

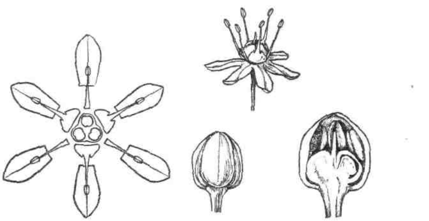


FIG. 199. The floral parts of *Allium Cepa*.

The sepals and the petals alternate with each other and there are three members in each of these whorls. The stamens are in two whorls of three each, and the stamens of the outer whorl are opposite to the sepals and those of the inner to the petals. The ovary is superior and three-celled. The flowers are pedicelled and are in umbels; but the opening of the flowers is from the centre to the peripheral part of the circumference. So, though the inflorescence is an umbel, it is cymose in character. The flowers of Crinum are also in umbels, and they do not differ very much from the Onion flowers in their structure, except that the parts are larger and the ovary is *inferior*.

From a study of the structure of a few flowers, we clearly see that the parts of a flower are subject to considerable variations. So, it would be instructive to deal with the parts

of the flower, in a general way, noticing only the more striking variations presented by them.

The calyx.—As the main work of the calyx is protection of the other parts of the flower, it is obvious that it should be found in the flowers of all flowering plants, except in cases where the protection is given by some other part. For instance, in the flowers of a head in a Compositæ, such as, Tridax and Vernonia, the bracts forming a sort of envelope to the head do this duty. The flowers of grasses are devoid of calyx, the necessary protection being the work of the very well developed bracts (these are called glumes). The calyx will have done its work, as soon as the flowers open, and so it withers and falls down sooner or later. If the sepals fall off

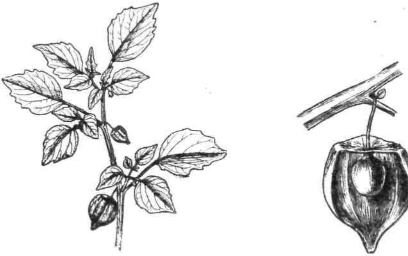


FIG. 200. The large persistent calyx in the flowers of *Physalis minima*. (The branch reduced and the fruit nat. size.)

as soon as the flower opens (as in *Argemone mexicana*), they are said to be *caducous*; when they fall some time after the opening of the flower, they are *deciduous* and, if they remain without falling off, then they are *persistent*. In some cases the calyx is not only persistent, but also grows with the fruit, and not infrequently envelopes it. The Brinjal fruit possesses a persistent calyx growing along with the fruit, but it does not overgrow and enclose it. On the other hand, in the fruits of Physalis and Withania this part is persistent and grows very much more than the fruit and ultimately covers the fruit fully.

In a calyx the sepals may be free, or they may be united. The sepals may be regular and all alike as in Tribulus and *Gynandropsis*, or they may be irregular as in Cassia, Ipomœa and *Cæsalpinia*.

The surface of the calyx may have various outgrowths in the form of hairs, scales and glands. In colour this part is green in most plants, although in a few cases they happen to have the colour of the petals : and then the calyx is said to be *petaloid*.

The corolla.—This is the most attractive and beautiful part of the flower and it is also the conspicuous part by reason of its colouration. We meet with greater variations in the corolla than in the calyx. The petals are either free, or united, as in the case of sepals. If the corolla is tubular and widened above as in Datura, it is said to be *funnel-shaped*.

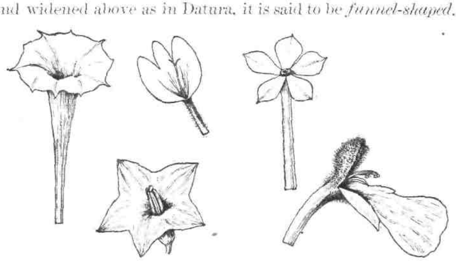


FIG. 201. Corolla and their forms. Funnel-shaped, ligulate, hypocrateriform, rotate and labiate, respectively.

It is described as *hypocrateriform*, when it is tubular with the limbs spreading at right angles. Such a one is seen in *Vinca rosea*. This may also be described as *salver-shaped*. A monopetalous corolla like that of *Solanum Melongena* is *rotate* or *wheel-shaped*. A tubular corolla may have its upper portion divided into two parts, and then it is said to be two-lipped or *labiate*.

In the heads of plants of the family Compositæ there are two kinds of flowers ; one with a *tubular* corolla in the centre of the head, and all round the margin of the head we

find the other kind with strap-shaped corollas, which are described as *ligulate*.

The petals of a corolla may all be similar in shape and size and then it is regular. In several flowers the corolla is irregular. For instance the petals of Crotalaria and Dolichos flowers are not all alike. Of the five one is larger than the others, and it is called the *standard*; two of the petals are alike and are called the *alæ* or *wing petals*; the remaining two together resemble a boat in shape, and, therefore, these are called *keel petals*. A corolla consisting of petals thus modified is called a *papilionaceous* corolla.

There are flowers wherein the corolla possesses outgrowths of various forms. Such outgrowths are known as the *corona*. The flowers of Nerium, Wrightia, and Cardiospermum have coronas in the corolla. Another very good example of a corolla with a corona occurs in Passiflora.

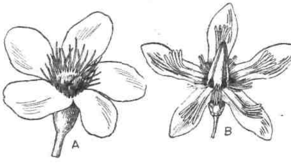


FIG. 202. Corollas with Corona. A, flower of Nerium; B, flower of Wrightia.

Before considering the stamens we should deal with the folding of the sepals and the petals in the bud, because the mode of folding is more or less uniform and common to a group or family of plants. For instance, the folding of the petals seen in the flower buds of Crotalaria and Dolichos occurs in all the flowers of plants belonging to the family Papilionaceæ. The petals or sepals just touch each other by their margins without overlapping in some flowers, as in the case of the petals of Calotropis; then they are said to be *valvate*. These, instead of touching by their edges, may overlap each other. For instance, the petals of Hibiscus are as it were twisted, so that one margin of a petal lies above the hinder

margin of the petal in front of it and the edge behind is over-lapped by the front margin of the petal which lies behind it. *All the petals are folded thus. This mode of folding is* called *contorted* or *twisted*. In this method of folding there is regularity : every petal has one of its edges covered and the other covering. In *some flowers this regularity is* disturbed by one or more petals getting fully in so that both the margins are inside. Then the mode is *imbricate*. There are several special cases of imbrication and one in which two petals have both their edges outside, two with both their margins inside and one with one margin in and the other out, as in the sepals of Ipomœa and Tribulus, is called *quincuncial*.

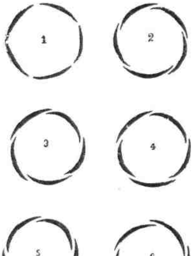


Fig. 203. Aestivation of the floral leaves in the flower bud. 1, valvate : 2 and 6, contorted *or twisted* : 3 and 5, imbricate : 4, quincuncial.

The Stamens.—The stamens of a flower are also subject to considerable variation. The filaments of the stamens may *be free as in Tribulus, or they may become united into one* bundle, as in Hibiscus and Abutilon. When the filaments are united in one bundle the stamens are said to be *monadelphous* ; if they form two bundles as in Dolichos, then they are *diadelphous*. Occasionally we meet with stamens whose anthers alone are united, the filaments being free. In this case the anthers are said to be *syngenesious*.

Usually the stamens have filaments, but in some cases they are reduced to anthers, as in Orchids and Aristolochia. In both these cases the anthers are attached directly to the pistil, and so the stamens are said to be *gynandrous*.

There is variation in stamens as regards number ; they may be many (indefinite), as in the flowers of *Argemone mexicana* or a definite number may be present as in the flowers of Tribulus. The filaments of stamens may all be equal in

length, or there may be variation even in this respect. For instance, in the flowers of the Mustard and Radish plants there are six stamens, four with longer filaments and two with shorter ones. In this case they are said to be *tetradynamous*. In some flowers, as in the case of Justicia, Leucas and Stemodia, there are four stamens two being longer than the other two ; and in this case, the stamens are described as *didynamous*.

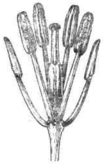


FIG. 204.
Tetradynamous stamens.

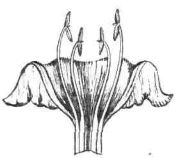


FIG. 205.
Didynamous stamens.

The stamens may spring directly from the receptacle as in Argemone and Tribulus, the ovary being superior : or they may be attached to the corolla. In the former case the attachment being below the ovary, the stamens are described as

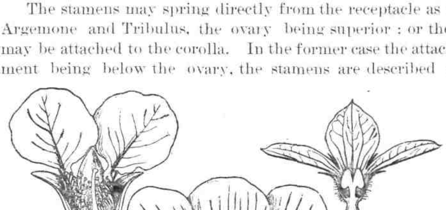


FIG. 206 A, Perigynous ; B, Hypogynous and C, Epigynous flowers.

hypogynous or *inferior*, and in the case of the latter they are *epipetalous*. We find in some flowers stamens springing, as it

were from the top of the ovary, as in Guava flowers. Then the stamens are said to be *epigynous*. In the pomegranate flower and in the rose flower the stamens are attached to the edge of the receptacle and round the ovary. So the stamens are said to be *perigynous*.

The anthers are attached to the filaments in various ways. An anther attached to the top of the filament at its base is said to be *basifixed* or *innate*. Examples for this are furnished by Cassia. Sometimes the filament becomes prolonged behind the anthers, when the anther is described as *adnate* or *dorsifixed*. In some rare instances as in grasses, the anther is attached to the top of the filament just at a point, so that it moves freely and then the anther is said to be *versatile*. The part of the filament to which the anthers are attached is called the *connective*. This part becomes very conspicuous in some plants by becoming prolonged beyond the anthers, as in Anona, Adenanthera and Trichodesma. The prolongation may also have appendages as in the flowers of Nerium. (See fig. 209.) The close approximation or separation of the lobes of an anther depends upon the development and growth of the connective. When the connective is large and well developed, the anther lobes are far apart. Even with poorly developed connective the lobes of the anther remain quite separate, and examples for this are afforded by Justicia and Stemodia. In rare instances, as in Ocimum and Salvia, the connective becomes prolonged into two arms, one of these arms remains very short and bears no anther lobe, whereas the other one is long and carries an anther lobe.

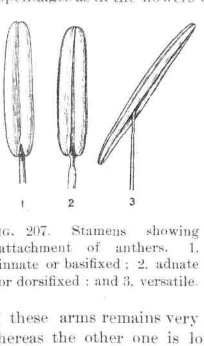


FIG. 207. Stamens showing attachment of anthers. 1. innate or basifixed; 2. adnate or dorsifixed: and 3. versatile.

The dehiscence of anthers is also varied. In most cases the anthers open by means of longitudinal slits. Instances for this are seen in Datura and Tribulus. They open by apical pores in Cassias and Solanums. There are also anthers

opening by special lids or valves. Anthers of Mahonia, Berberis and those of the plants belonging to the family Laurineæ are of this sort.

In the case of the dehiscence by a longitudinal slit the face of the anther may be towards the pistil or the petals; in the former case the anther is said to be *introrse*, i.e., inside, and in the latter *extrorse*.

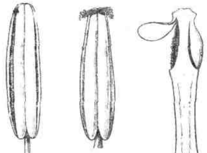


FIG. 208. Dehiscence of anthers. 1, longitudinal; 2, by apical pore; 3, valvular.

As in the case of petals, we have in some cases outgrowths from the stamens also. These are called *staminal corona*. We have already referred to the appendages of the connective. They may also arise from filaments as in Calotropis.

The Gynæceum or *the Pistil.*—We have now to deal with the innermost whorl, the pistil, or the female part of the flower. In the Tribulus flower this part consists of a five-celled ovary with a very short style terminating in a five-rayed stigma.

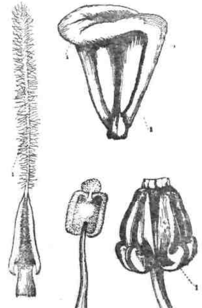


FIG. 209. Appendages of the connective and filament in Nerium, Polyalthia, *Adenanthera* and Calotropis.

Within the ovary there are five rows of ovules one in each cavity. These rows are attached to a central axis, and the place of attachment of ovules is termed the *placenta*. In Tribulus the placentas are arranged around a central axis, and this arrangement is called *axile placentation*. As further

examples for this kind of placentation, we may mention Ipomœa, Hibiscus and Aristolochia.

In *Gynandropsis pentaphylla* we have an ovary, single-celled, with a short style terminating in a conspicuous stigma. There are three or four placentas on the wall of the ovary, and so the placentation is said to be *parietal*. The ovary of Dolichos also has a single cavity, but with only one placenta. Instances of parietal placentation are found in Argemone, Cucurbita, Modecca and Ionidium. The ovules are also borne sometimes on an axis springing from the base of the ovary. This kind of placentation is termed *free-central*, because the central axis bearing the placentas is quite free and not connected with the wall of the ovary. In Portulaca and Polycarpæa, the placentation is of this kind.

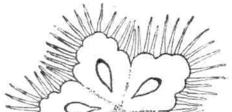


FIG. 210. A transverse section of the ovary of *Tribulus terrestris*.

The ovary is considered to consist of a number of carpels and this corresponds with the number of the cavities in the ovary.

An ovary consisting of only a single carpel, as in Dolichos, Crotalaria and other leguminous plants, is termed a *monocarpellary* or *simple* ovary ; in this case we find only one placenta. In Hibiscus, Tribulus and Aristolochia there are more than one, and so the ovaries in these cases are *compound*. The cavities in the ovary may or may not correspond with the number of carpels. For instance, in the ovary of Gynandropsis, Cucurbita and Portulaca we find only one cavity and yet, in all these cases, the ovary should be considered compound, because of the plurality of the placentas.

All the carpels in an ovary may be united as in Tribulus, and then it is said to be *syncarpous* ; on the other hand if they are free as in Polyalthia (see fig. 242), it is *apocarpous*.

For the sake of convenience in description, the part of the placenta bearing the ovules is called the *ventral suture* the

part opposite to it being termed the *dorsal suture*. In Tribulus, Aristolochia and Hibiscus the narrow portion of the carpel near the central axis is the ventral and the broader back portion is the dorsal suture.

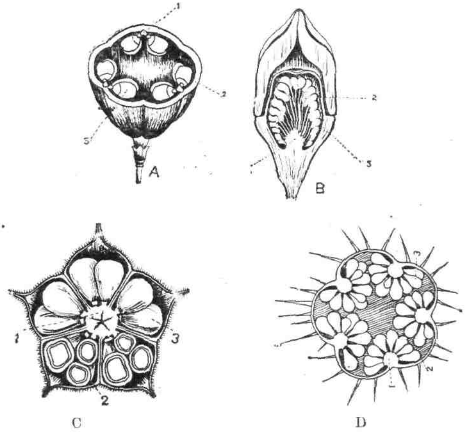


FIG. 211. Different kinds of placentation. A, D, parietal; C, axile; B, basal. 1, placentum; 2, wall of the capsule; 3, seeds.

In many plants the styles are quite distinct and they may be long or short, but there are also flowers in which it is very short or absent. The style in many cases becomes divided into branches at the free end, the branches corresponding in number with the carpels. The stigma is situated at the free end of the style, or on the top of the ovary. It may be simple or it may become branched, sometimes very much so as in the ovaries of grasses. We shall have to speak about this part later on in connection with pollination.

We have already learnt that the flower stalk bears the parts of the flower at its free end; and this end which is

termed the *receptacle* (also *torus* or *thalamus* by some authors) is subjected to some modification. It is in some flowers somewhat swollen, as in Argemone and Tribulus. In this case all the parts of the flower arise from the top of it, the ovary being superior, and the other parts below it *(Hypogynous)*. As already pointed out, the ovary is inferior in Cephalandra and Crinum, but the other parts are superior *(Epigynous)*; and this is due to the modification of the receptacle. This structure instead of remaining convex becomes hollow, and encloses

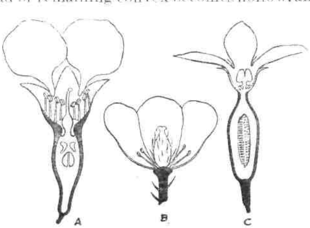


FIG. 212. The receptacle and its modifications. A, receptacle fused with the ovary, only at the base ; B, receptacle separate and prominent ; C, receptacle completely fused with the ovary.

the ovary. The wall of the ovary becomes fused with the receptacle. Sometimes the receptacle becomes hollow, but remains open at the top, as in the flower of pomegranate. The calyx, corolla and the stamens spring from the prolonged edge of the thalamus *(Perigynous)*.

CHAPTER XIII.

THE ESSENTIAL ORGANS AND THEIR FUNCTIONS.

THE *main function of the flower is the production of seeds*, and for the setting of the seeds two distinct processes are necessary. They are the transference of the pollen-grains from the anthers to the stigma (pollination), and a fusion of a bit of the protoplasm of the pollen-grain with a portion of the protoplasm within the ovule (fertilisation). We know that the parts of the flower directly concerned in these processes are its essential organs, the stamens and the pistil.

For the clear understanding of these two processes, a knowledge of the essential organs is necessary. The stamens are the parts intended to produce the pollen-grains. A stamen usually consists of a filament and an anther, but it is the anther alone that is of importance. The filament is only a stalk supporting the anther, and we have many instances in which the filaments are absent, the stamens being reduced to mere anthers. To study the structural details, the stamens of Tribulus may be used, *as it is typical of the anthers of a good number of plants. A transverse section of this anther reveals* two distinct lobes with two cavities in each, filled with pollen. But the lobes of an old anther present only a single cavity, as the two cavities get fused. The anther lobes are held together by the connective, which is traversed by a vascular bundle. The wall of the anther consists of two layers of cells, an outer layer or the epidermis and an inner layer in which the cells have special thickenings *(and hence called fibrous cells). This differentiation in the cells of the wall of the anther is intended* to facilitate its dehiscence. The outer wall of the cells of the epidermis bulges slightly outwards and there is protoplasm within these cells. Until the maturity of the anther these cells remain in a turgid condition. The pollen grains take some time to develop and until they are fully formed they

need protection. So the wall of the anther remains intact and does not burst, till the pollen is ripe enough for shedding. As long as the epidermal cells are turgid they exert pressure on the fibrous cells lying below the epidermis. As the anther approaches maturity the epidermal cells begin to lose water gradually. This means the gradual lessening of the pressure on the fibrous cells and, as soon as they are freed from it, they tend to expand and assume their natural size. The removal of compression on the fibrous cells leads to the curling of the anther wall. This, of course, causes the wall to break in some place where it is weak.

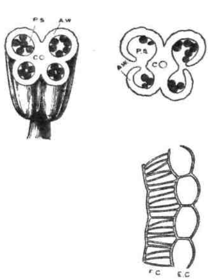


FIG. 213. Structural details of the anther of *Tribulus terrestris*. C, connective; A.W, anther wall; P.S. pollen sac. The third figure is the anther wall highly magnified. F.c, fibrous cells; E.c, epidermal cell.

The pollen-grain of *Tribulus terrestris* is round and it is only a bit of protoplasm enclosed by a cell wall in which two distinct layers, an outer cutinised and an inner cellulose layer, can be distinguished. The outer layer is thickened in a peculiar manner as shown in fig. 214. The inner layer is smooth and uniformly thick. There is a great deal of variation in size and form, and the sculpturing of the outer layer in the case of the pollen-grains, according to the species of the plant. Those of very showy flowers are in many cases provided with spiny or other kinds of projections, or the outer layer may be sticky. In a few cases, we find some spots in the wall formed beforehand for the coming out of the pollen-tube.

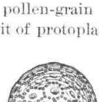


FIG. 214. Pollen-grain of Tribulus very highly magnified.

Some pollen-grains have *special lids* also, as in the case of Cucurbita.

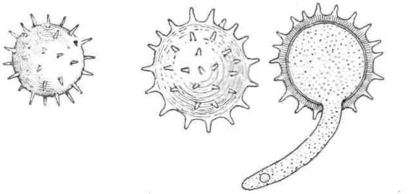


FIG. 215. Pollen-grains of Hibiscus and Thespesia (highly magnified). *Note the germination of the grain.*

The free end of the style or the stigma is the part intended *for the reception of the pollen. It has to catch the pollen-*grains and retain them, and also to assist them to germinate. The surface of the stigma is usually rough due either to papillae or hairs, and a sticky juice containing some sugar is also secreted by it. Both these conditions are useful in retaining the pollen-grains on the stigma.

Sometimes the stigma becomes very much branched and is *consequently plumose*, as in the case of grasses. It is said that the pollen-grains are safeguarded *from the attacks* of bacteria, by the stigmas secreting some substance detrimental to their growth.

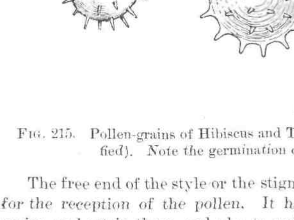


FIG. 216. Stigma of *Hibiscus*. *The* first figure shows the five stylar branches bearing the stigmas (slightly magnified) and the second figure is a stigma with pollen-grains (highly magnified).

A stigma is not always *receptive*; it becomes receptive as soon as the flower opens and generally continues to be so for sometime, this period varying with the kind of the plant.

The sugary juice secreted by the stigma seems to be necessary to stimulate the pollen-grains to germinate. It is only when the stigma is receptive that we find the sugary juice, and if it is absent it is an indication that the stigma is not receptive.

The ovule which develops into seed after fertilisation lies within the ovary. It does not develop into a seed unless a

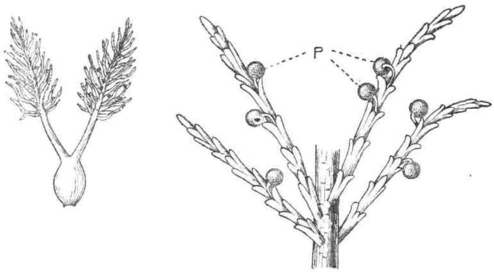


FIG. 217. Stigma of a grass plant. The first figure shows the whole of the pistil and the second shows the five branches of the stigma with pollen-grains germinating as seen under high power. P, pollen-grains.

bit of protoplasm from the pollen-grain finds its way into the interior of the ovule and mixes with a definite part of the ovule. When the ovule is fully formed and ready to receive the bit of protoplasm from the end of the pollen tube, it consists of a large cell, called the *embryo-sac*, amidst a mass of cells. This mass is covered, except at the top, by two membranes called the *integuments*. The opening at the top is called the *micropyle*. The embryo-sac at this stage possesses two groups of nucleii one at the top and the other at the bottom. In each of these groups, there are three nucleii. Of the three lying at the top of the sac close to the micropyle, one nucleus is slightly larger than the others, and this is called the *egg-cell*. The other two cells seem to be helpful in directing the contents of the pollen-tube to the embryo-sac. The three cells at the other

or far end of the embryo-sac do not seem to take any part in the formation of seed. Within the embryo-sac, midway between the two groups of nucleii, lies a single large nucleus, which is called the nucleus of the embryo-sac, or the *secondary nucleus*.

The pollen-grain, deposited on the stigma, emits a tube and this comes to the top of the embryo-sac finding its way through the style and the micropyle. At the end of the pollen-tube we find two nucleii, and both of them get into the interior of the embryo-sac and one fuses with the *embryo-cell and the other with the* secondary nucleus. This fusion of the nucleii of the pollen-grain with those of the ovule is really the process of fertilisation. It is only after this fusion that the egg-cell is capable of division and development into the young embryo plant that we find in the seed. The secondary nucleus divides and gives rise to the endosperm, after the fusion of the *nucleii*.

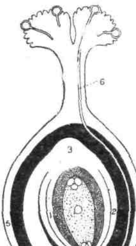


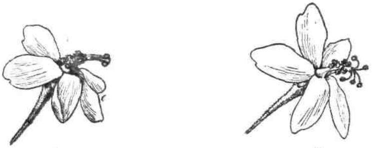
FIG. 218. A diagram to illustrate pollination and fertilisation. 1, inner integument; 2, outer integument; 3, chalaza or base of the ovule; 4, funicle; 5, wall of the ovary; 6, pollen-tube. The ellipsoidal white space within the integuments is the embryo-sac.

Now it is obvious, that, for the production of offsprings, the fusion of the male and female cells is essential even in the case of plants, as it is in the case of animals. Further the offsprings are likely to be better in quality when the sex cells uniting together are from different plants.

The pollen-grains of a good many of the flowering plants have no power of spontaneous movement. So they have to depend upon some external agency for the pollination of their flowers. Even in the case of plants with bisexual flowers, extraneous aid is necessary for pollination. The transfer of pollen to the stigma from the anthers of the same flower, as well as from the anthers of a different flower on the same

plant, is called *self-pollination*. Pollination of the stigma of a flower with the pollen from flowers of a different plant is called *cross-pollination*.

As a matter of fact, self-pollination occurs in several plants, especially annuals. In some cases flowers are self-pollinated regularly, and such flowers are usually small and inconspicuous without smell or honey. As examples for this, we may mention the Chenopodiums. We have also certain plants wherein self-pollination is made impossible in the earlier stages, but later, just before fading, this becomes possible. For instance, in the flowers of *Hibiscus micranthus* and *Abutilon indicum* the style branches project a little above the anthers just when the flowers open, and so the pollen cannot reach the stigma. It is evident that pollen from a



A B

FIG. 219. Flower of *Hibiscus micranthus*.
A. morning and B. evening positions.

different flower has to be brought and deposited on the stigmas by some agency, either wind or insects. If the stigmas fail to receive foreign pollen, they bend down so as to come near the anthers in the same flower, to be at least self-pollinated. In both these flowers, the petals close and press on the style branches and thus assist them in coming near the anthers. In some flowers, as in *Evolvulus alsinoides*, the style lies bent away from the anthers just, at first, but later it changes its position, so as to bring the stigma nearer the anthers to make self-pollination possible.

The flowers of *Mirabilis jalapa* are also adapted for self-pollination, when cross-pollination fails to occur. These flowers open towards the evening and emit a very strong scent. Just then, both the stamens and the stigma are far exerted, the stigma alone projecting above the stamens.

Usually two species of moths visit these flowers and if they are not visited by any insect, the stigma manages to get self-pollinated either by the elongation of the stamens or by the slight bending of the style, so as to reach the anthers.

The flowers of some Compositæ are specially interesting in that they have special adaptations in their floral mechanism to secure self-pollination, should cross-pollination fail to take place. For example, in the plant *Tridax procumbens*, a weed found everywhere, the heads have bisexual flowers in the central portion of the disc and the ray flowers are all female. The stamens are epipetalous and the anthers are adherent, so as to form a tube. The style is bifid and the branches are pressed together, in such a manner that the receptive surfaces are in contact and so not exposed. At first, when the flowers are unopened, the style is short, but, as soon as the flowers begin to open, the anthers dehisce and the style elongates. So the pollen, lying in the anther tube, gets pushed out and remains at the top of the anther tube. The tip of the style may also carry a small amount of pollen, besides what may adhere to the hairs of the style branches on the outer surface. The style grows and after projecting a little above the anther tube, the branches separate and diverge, exposing the receptive surface. The stigmas thus exposed remain receptive for some time so that cross-pollination may occur. If the stigmas fail to receive pollen by insect visits, the style branches diverge still more and even curl round, so that the receptive surface may come in contact with the pollen adhering to the lower surface of the style branches, or with the pollen lying at the top of the anther tube. Self-pollination is thus ensured, if cross-pollination has not already taken place.

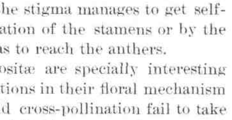


FIG. 220. Floral mechanism of the flowers of *Tridax procumbens*.

Instead of this makeshift arrangement to secure self-pollination, when cross-pollination is a matter of some difficulty, some plants produce two distinct sets of flowers, one adapted for cross-pollination and the other for self-pollination. In *Commelina benghalensis* we have a plant of this sort. The beautiful blue flowers are regularly cross-fertilised and the underground or low-lying inconspicuous flowers that remain as buds without opening are self-fertilised. These inconspicuous flowers are called *cleistogamous* flowers.

Charles Darwin, the great English naturalist, has proved by a series of experiments with different plants that cross-pollination is more advantageous to a plant than self-pollination. If we examine flowers of a number of wild plants growing in a place, we find in them numerous contrivances favouring cross-pollination to the exclusion of self-pollination. Recent workers in the field of plant-breeding have also established beyond doubt, that cross-pollination is not only more advantageous to the plant than self-pollination, but it also confers on plants certain racial advantages.

A most perfect arrangement to ensure cross-pollination is to have the essential organs on separate flowers. We find a host of plants in which the flowers are unisexual. In some plants, as in Cucurbita and Ricinus, we find both male and female flowers on the same plant (monœcious), in others, as in *Cephalandra indica* and in some palms, the male and female flowers are found on different plants and not on the same individual (diœcious).

Bisexual flowers become adapted for cross-pollination to the exclusion of self-pollination, by having the essential organs active at different times. The stigmas may mature and become receptive prior to the anthers. In Cumbu spikes *(Pennisetum typhoideum)*, the stigmas protrude from the spikelets and become receptive, while the anthers are still within the glumes. Such flowers are called *protogynous*. The female sexual organs in the protogynous flowers are ready for fertilisation long, before the anthers are ripe in the same flower, and, therefore, the flowers have to be pollinated only by the pollen of older flowers. There are also plants wherein the stamens shed their pollen prior to the receptivity of the stigmas. The flowers are then termed *protandrous*.

Protandry seems to be more common than protogyny. Flowers of several Compositæ, Malvaceæ and *Andropogon Sorghum* are protandrous. Pollination in this case is effected by the pollen from younger flowers.

In very many plants self-pollen is sterile, as in the case of many leguminous plants. The pollen in the flowers of certain orchids is said to act as a poison, if it falls on the stigma of the same flower. There are also instances in which the pollen from the same flower fails to fertilise, if foreign pollen falls on the stigma, soon after self-pollination. This means that foreign pollen is prepotent over self-pollen.

Another very effective arrangement promoting cross-pollination exists in the flowers of several species of Jasminum. The corolla in all cases is tubular and the stamens are epipetalous. In some flowers the style is short reaching only half the length of the tube, whereas the anthers are at or near the throat of the corolla. On the same plant we also find flowers in which the styles are longer and coming up to the throat of the corolla, while the stamens remain within the tube about midway.

In the case of land plants it is obvious that for cross-pollination some extraneous aid is necessary, because of the fixity in position of these plants and of the absence of spontaneous movement on the part of the pollen-grains. The agents usually active in this work are wind and insects and, in rare cases, water. Plants depending upon insects for fertilisation are very many and those pollinated by wind are not inconsiderable.

When plants depend upon wind for pollination, the stigmas have to wait for the pollen that may be wafted by the wind, and this is purely a matter of chance. Therefore, we should expect to find certain conditions specially favourable to this process in these plants. In the first place, large quantities of pollen should be availabie to ensure pollination. Winds may carry large quantities of pollen, but the pollen likely to fall on the stigmas can only be proportionately very inconsiderable. And, therefore, the flowers that are to be wind-pollinated should stand out far above the foliage leaves, so that the pollen may not be hindered from reaching the flowers. This is exactly what we find in the case of

windfertilised plants. For instance in grasses which are wind pollinated the inflorescence rises far above the level of the foliage: in the case of trees dependent on wind for pollination, flowers appear, in most cases, at a time when the leaves have *all* fallen. As an example we may mention the tree, *Odina Wodier*.

The abundance of pollen is secured either by increase in the number of stamens in bisexual flowers, or by having a large number of male flowers. Sometimes the anthers become larger and produce plenty of pollen. To give a vivid idea of the abundance of pollen produced by this class of plants, we may mention the male spikes of Pandanus. A single plant is capable of producing a very large quantity of pollen. It has been computed by some American botanists that a moderate sized *Zea Mays* plant produces about 50,000,000 pollen grains. The pollen produced by these plants should also be adapted for being carried by the wind. So these grains are smooth, light and dry. The anthers are in most cases versatile, an arrangement best suited for the shaking out of the pollen very readily.

The stigmas also have certain adaptations so as to enable them to catch the stray pollen floating in the air. They are branched and plumose, thus getting a large amount of surface. All grasses and sedges, some Amaranths, Ricinus, Pandanus and Odina are wind-pollinated.

From this we see that wind-pollination involves the expenditure of a large amount of energy. As the pollen-grains are composed almost wholly of protoplasm, a material most difficult to manufacture, this enormous production of pollen-grains cannot but be a drain on the resources of the plant. But this is necessary for ensuring pollination.

We have now to consider plants that are pollinated by insects. For successful cross-pollination flowers should be visited regularly and systematically by insects. Casual and erratic visits, or indiscriminateness in the choice of flowers for visits are not likely to be beneficial. Insects should have some inducement to visit the flowers. Flowers, as we know, produce pollen and honey, and both these substances are sufficient inducements to attract the insects and also ensure their visits. By the mere secretion of honey in the flowers

the insects cannot be allured. To ensure their visits, it is absolutely necessary that the place where honey is secreted should be made known to them. The colours of flowers are meant to show them the place where honey may be obtained.

The infinite variety in colour and form of the flowers, as well as the different scents, is intended to attract the insect. In many plants the petals or the corollas are large and coloured so as to be very conspicuous. If the flowers are small, they are rendered conspicuous by being massed together. Sometimes instead of the petals, bracts play the same part, as in Bougainvillæa. Stamens also partake in this work, in Neptunia and Dichrostachys. There are also instances of flowers wherein the calyx becomes highly coloured, while the *corolla is absent. The brightly coloured part in the flowers* of Mirabilis and Boerhaavia is the calyx. Even when the petals are present the sepals become coloured like the petals, and we have such examples in Cassia and Cæsalpinia.

The colour and the scent of the flowers are no doubt quite sufficient to attract the attention of the insects, but to ensure the regular visitation of insects this is not enough. Something more substantial should be offered to them to induce them to frequent the flowers very regularly. The *pollen* serves as food, or as material for building the hives for some insects such as *the bees. Further, nectar or* honey is also secreted in several flowers. Insects such as moths and butterflies live mostly on nectar. As both these substances, honey and pollen, serve as food for these insects, they come to the flowers.

FIG. 221. Butterfly sucking honey from the flower of Petunia.

Insects that visit the flowers are bees, butterflies,

moths and flies. All these insects have sucking apparatus, which in the case of flies are short and in moths and butterflies they are very long and coiled like a spring. Bees take *in honey and also gather pollen: moths, butterflies and flies* drink only honey. As stated above, these insects visit the flowers, because *they get food in the form of honey or pollen*. Therefore, the secretion of nectar or honey is essential to ensure their visit.

In the case of insect-pollinated flowers, pollen need not be abundant. So, in these flowers, stamens are generally fewer in number. Further, the grains have usually a rough surface which often also becomes sticky. Stigmas need not have a large amount of surface as in the case of wind-pollinated flowers. The special adaptations in these flowers are so perfect that pollination is a certainty.

The nectar or honey is secreted usually by a disc at the base of the ovary. There are also instances *of petals and* sepals having nectaries either as glands, or as special pouches, sacs or spurs. The position of the nectary and the arrangement of the other parts of the flower are such as to make it impossible for the insects to get at the honey, without at the same time effecting pollination. It must also be remembered that, if the visit of the insect is to be of use in pollination, it is absolutely necessary that the part of the body of the insect which comes in contact with the *anthers should also come in contact with the stigma; otherwise* pollination will not take place.

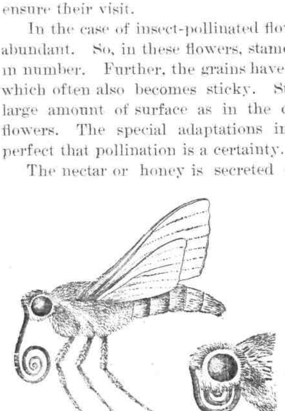


FIG. 222. Head of Moth showing the length of the proboscis.

In flowers in which the corolla is regular and shallow any insect can get at the honey and effect pollination. For instance, in the Tribulus flower there are honey glands at the

base of the stamens and between the petals ; the corolla is shallow and the stamens stand erect and so any insect, a bee, or butterfly or a fly can get at the honey. In trying to get at the honey the lower portion, or the sides of the insect must necessarily get dusted with the pollen, and as the stigma is also of the same height as the stamens it must also touch the same part of the body of the insect.

Flowers having long tubular corollas like those of Vinca and Jasminum, or papilionaceous corollas like those of Phaseolus, Indigofera and Vigna are not meant to be visited by all kinds of insects. Only butterflies and bees are able to get at the honey and in their manœuvres in search of honey they cannot help pollinating the flowers. Other insects cannot get at the honey and so they do not visit these flowers.

Colour of the petals though intended to show off well by contrast, is probably not capable of attracting insects as well as the scent of flowers and the smell of honey. The Mirabilis flower affords an example in support of this statement. This flower is visited by one or two species of the hawk moths ; and there are several varieties of Mirabilis and in all of them the flowers open towards the evening and emit a strong scent. Some time after sunset the flowers that are white, light-yellow or cream-coloured alone can be seen and the magenta-coloured flowers cannot be seen. Yet the moth visits both the white and red flowers with equal ease. Insects cannot see the colour from a distance, their range of vision in this respect being limited to within a few feet. Again they are able to see some colours better than others. Bees are said to perceive blues better than yellow. Scarlet does not seem to attract them. Many of the insects visiting the flowers are usually busy with only one kind of flower at a time. For instance the common Carpenter bee was seen while sucking honey from *Bauhinia tomentosa* flowers. For over quarter of an hour it continued to hover about the same flowers, although there were several other flowers close by, that are usually visited by these bees. On another occasion this bee was thus visiting only the flowers of *Dolichos Lablab.*

Having considered the question of pollination in a general way, we shall now deal with a few flowers in a more detailed manner. The flowers of Papilionaceæ are specially adapted

for cross-fertilisation. At the base of the ovary there is usually a disc, which secretes plenty of honey. As the stamens are united by their filaments the honey finds its way into the staminal tube. Of the five petals, the standard is the chief attractive portion. It stands erect and is very conspicuous; in some cases besides being conspicuous it also bears some special marks which are supposed to serve as guides to the place where honey is secreted. The wing-petals invariably constitute a platform for the insects to alight and move about. The insect always sits on the wing-petals with its head directed towards the standard, whether there are special marks or not in it to direct the insect to the honey. Getting at the honey in these flowers is not at all an easy affair. It lies hidden at the base of the ovary and in the trough or cavity formed by the filaments. So it is only very intelligent insects that are likely to get at the honey.

When an insect settles on the flower and moves about, either the stamens or the stigma come out and touch the body of the insect. In some cases, as in *Crotalaria verrucosa* and *Tephrosia maxima*, when insects alight on the wing-petals and move about, pollen-dust is ejected from the pointed tips of the keel-petals first and then the stigmas come out when the insects visit the flower later.

In the flowers of *Vigna Catiang* the filaments of nine stamens are united, one stamen alone being free. At the base of the ovary and around it there is a disc secreting honey. The petals are all connected at the base by means of outgrowths, dents and foldings in such a manner that the standard stands erect, the wing-petals spread themselves out horizontally so as to serve as a platform and the keel-petal remains below. The margins of the keel-petals are united, both above and below, except at the free end where there is a small opening just enough for the emergence of the stigma. When the wing-petals are pressed down, the keel gets depressed and the stigma pops out, and when the pressure is removed, it resumes its original position. In this flower the anthers shed their pollen, before the stigma becomes receptive. Although the stigma is close to the anthers, the pollen does not reach it, because of the hairs found on the style a little below it. Even if a few grains fall on it they will not

germinate, as the stigma is not receptive. When a bee or butterfly alights on the wing-petals the stigma comes out and brushes against the lower part of the body of the insect. If there is pollen already on the body of the insect the stigma gets pollinated. If on the other hand the visit is at a time when the anthers are dehiscing, the lower part of the body of the insect will be dusted with the pollen, and the same part of the body is sure to come in contact with the stigma when it goes to another flower.

In the plant *Indigofera enneaphylla* the floral mechanism is of a peculiar sort. In the flower the keel-petals have short spurs at their sides and they are intended to support the wing petals and keep them in a horizontal position. A very slight pressure on the wing-petals is enough to depress the keel-petals and separate their upper margins. As soon as the keels get depressed, the stamens and the style seem to come up with a jerk and remain outside. The essential organs cannot regain their original position, because the petals fall off as soon as the flower has received a single visit. So in this case one single visit of the insect is enough for cross pollination. Instances of the same kind of explosive arrangement are afforded by the flowers of *Abrus precatorius* and *Alysicarpus rugosus*.

The flowers of Phaseolus are very interesting in their structure and behaviour. Like other papilionaceous flowers these also depend on insects for pollination; at any rate the arrangement of the petals and the position of the essential organs are such that self-pollination cannot take place. The keel-petals are in this flower prolonged into a beak and the beak is in the form of a spiral. The end of the spiral in the flower of *Phaseolus trilobus* and *P. Mungo* is towards the right, looked at from the front. The right keel-petal possesses a spur which supports the right wing-petal and helps it in retaining a horizontal position, so that it may serve as a platform for insects visiting this flower. There is a distinct passage between the right wing

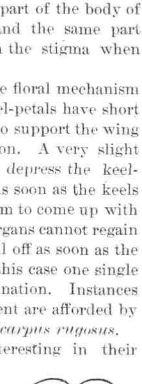


FIG. 223. The floral mechanism of *Phaseolus trilobus*.

petal and the end of the keel-spiral, leading to the base of the standard where the honey is found. The left wing-petal lies higher than the right over the keel on the left side. An insect can get the honey only from the right side. On the left side the wing-petal, the keel and the standard are all close together and there is no opening. An insect coming to this flower for the sake of honey will, of course, alight on the lower wing-petal on the right hand side. As soon as it alights on the wing and begins to search for honey there will be some pressure exerted on the wing-petal. The keel will also be depressed on account of the spur which supports the wing-petal. Then the stigma will come out through the opening at the end of the keel-spiral which lies just above the wing-petal which rests on the spur of the keel on the right side. Inasmuch as the insect is on the platform, the stigma touches the back part of its body. If the stigma is receptive and if the back of the insect's body is already dusted with pollen, pollination takes place. If on the other hand the insect visits a flower for the first time to start with, it will get dusted with the pollen, and the next flower visited will have its stigma pollinated.

In *Leucas aspera* and *L. linifolia* the corolla is bilabiate and the stamens are epipetalous and didynamous. The stamens and the style are enclosed within the upper lip of the corolla. Honey is secreted at the base of the ovary and when the insect alights on the lower lip of the corolla to suck the honey, the stamens and the stigma are released from the upper hood of the corolla. As both the anthers and the stigma are turned downwards they will touch the back of the insect; if the insect is already dusted with the pollen then the stigma will be pollinated, and in case the visit is for the first time the back of the insect gets dusted with pollen.

The flowers of Acanthaceæ have also special devices for pollination. In many plants of this family the stamens lie within the corolla in such a way that they cannot help coming in contact with the back of the insect when it sucks honey. Even small inconspicuous flowers are regularly visited by butterflies. On one occasion in the month of October while engaged in collecting plants, the tiny flowers of *Justicia procumbens* were constantly visited by the small

pretty violet butterfly, Zizera lysimon. At first the flowers of *Justicia procumbens* were not noticed; this small butterfly was seen hovering about and settling on this plant. On close inspection it was found to suck honey from the tiny flowers of the Justicia. These plants were not at all numerous and there were stray plants scattered all over the place. The violet butterfly continued to visit these flowers persistently for over twenty minutes. The insect proved a most satisfactory guide to lead to the places where this species of Justicia was growing. Similarly another butterfly, a white one with a red border on the front wings, was seen visiting the flowers of *Spermacoce hispida* with great assiduity. The flowers of *Tephrosia purpurea* were visited by a butterfly with golden yellow wings. The flowers of Tridax were watched to see what insects visit them for honey and pollen. Seven different species of insects were found visiting these flowers and they were Zizera lysimon, Colotis amata, Catopsila pyranthe, Terias hecabe, Parnara mathias and Ceratina viridissima.

There are flowers that are exclusively pollinated by the visits of flies. The flowers of Aristolochia and Aroideæ are of this kind. A very fœtid odour is usually emitted by some of the Aristolochias and in one species the smell is so strong as to attract flies from very long distances (fifty to hundred yards or more). In this flower the anthers are situated on the style below the stigma and they dehisce after the withering of the stigma. Inside the tubular perianth, when it opens there are found a number of hairs all directed inwards. (See fig. 194.) The flies get into the perianth tube easily. But they cannot get out of it with the same ease, on account of the hairs. This flower is protogynous and therefore it has to be pollinated by pollen from some other flower older than itself. When the flies get inside the flower they pollinate the stigma if they have already visited other flowers; if on the other hand the visit of the insect is its first visit, it gets dusted with the pollen. When the flies get into the flower, the anthers are usually immature and the flies cannot get out of the flower, until the anthers dehisce, because the hairs dry only then. Until that time the flies will be wandering all over inside, in search of a way to escape; and in their wanderings they

get dusted with pollen. By the time the pollen is liberated the hairs disappear and the stigmas fade, and the way becomes clear for the flies to escape.

The inflorescence of Aroids are particularly interesting on account of the arrangements existing in it for pollination. The spadix bears the unisexual flowers at its lower portion only, those at the very base being female and those above male. (See fig. 175.) Above or between these are a number of reduced flowers in the form of hairs directed downwards. The whole inflorescence is covered by a large spathe, the lower part of which forms a tube constricted a little above the region of anthers, or the hairs, whilst the upper portion is expanded

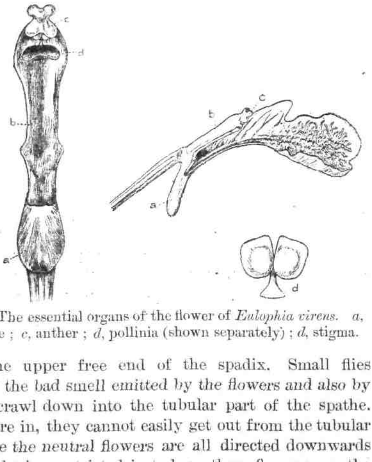


FIG. 224. The essential organs of the flower of *Eulophia virens*. *a*, sac; *b*, style; *c*, anther; *d*, pollinia (shown separately); *d*, stigma.

exposing the upper free end of the spadix. Small flies attracted by the bad smell emitted by the flowers and also by the spathe, crawl down into the tubular part of the spathe. Once they are in, they cannot easily get out from the tubular part, because the neutral flowers are all directed downwards and the spathe is constricted just above these flowers, or the anthers. The flowers are protogynous as in the case of Aristolochia, and so the insect pollinates the stigma if it bears pollen from another plant. If the flower happens to be the first one that is visited by the insect, the insect is

forced to stay within the spathe until the way is open for it to escape. The withering of the downward directed hairs and the dehiscence of the anthers take place together and therefore the flies escape with a coating of pollen. They cannot avoid this as the anthers are at the top of the inflorescence just at the level of the constriction or a little below it.

In the flowers of orchids we have a most perfect mechanism for securing cross-pollination although it is very complicated. As examples we shall select two species of orchids commonly met with in the plains. The orchid *Eulophia virens* grows amidst scrubs and its flowers are greenish with red streaks. There are three sepals and three petals ; the sepals are all alike, but one of the petals, the one lying on the lower side of the flower when it is open, is modified, and it is called the lip. In this flower the lip is slightly saccate at its back and the free front part is broad and in the flower it stands out as a platform for the insects to sit on. The short shallow sac secretes honey and the flowers are visited by butterflies. The anther is single and it is on the top of a column rising from the top of the ovary. (See fig. 224.) The pollen in this and all orchids is collected in masses called *pollinia*, and in this flower there are two such masses in the anther. Just below the anther there is a disc-like gland to which the two pollen masses are attached by means of strap-shaped stalks. The anther in the open flower lies just above the opening leading into the honey-sac. When the butterfly sucks honey the pollen masses stick on to its head, and so the insect carries away with it the pollen masses. The next flower that is visited by this insect is pollinated by the pollen masses sticking on to its head. The stigma lies just below the anther on the front side of the column. When the insect rushes into the flower to suck honey the pollinia cannot help touching the stigma because the pollinia assume a direction which will coincide more or less, with the position of the stigma.

In Habenaria we have another very common orchid of the plains. The flowers in this orchid are all pure white and the raceme springs from the middle of two or three elliptic leaves lying flat on the ground. They are very conspicuous by reason of the racemes. Both in the morning just before

sunrise and in the evenings the flowers are visited by moths. The lip is prominent below and it is prolonged at the back into a very distinct spur varying in length from quarter of an inch to one inch. The two lateral petals and the sepal lying above are united so as to form a hood. There is a narrow passage leading into the interior of the flower and the anther is situated on a column just above the passage leading into the spur. The pollinia have long stalks and the basal portions of the stalk protrude a little. When the moth gets in, the two pollinia stick on to the two eyes of the insect and when it flies to another flower the pollinia are rubbed against the stigma lying below the anthers and the masses adhere to the stigma as its surface is very sticky.

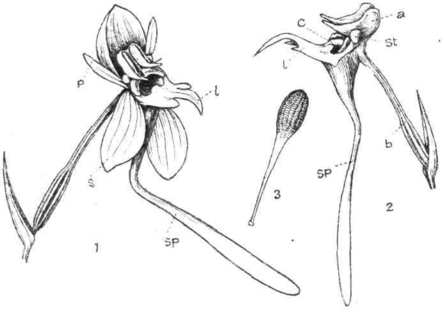


Fig. 225. The floral parts in *Habenaria platyphylla*. *S*, sepal ; *P*, petal ; *l*, lip or labellum ; *SP*, spur ; *a*, anther ; *b*, ovary ; *c*, stigma ; *St*, staminode.

In *Calotropis gigantea* (as also in all Asclepiadeæ), the pollen grains are held together in masses and there are ten pollinia. When an insect settles down on the top of the staminal column in the centre of the flower and moves about round the stigma, the pollinia adhere to the legs of the insects. When it flies to another flower the pollinium gets on to the stigma to which it will stick if it is receptive.

There are many plants whose flowers are usually pollinated by moths. As moths move about only during the night or in the dusk, these flowers have white corollas, open in the dusk and also emit a strong scent at this time. The flowers need not be irregular as a platform is not needed, because moths do not alight and they only hover in front of the flower. We may mention as examples Ipomœa, Tobacco, Mirabilis and Jasminum. In these flowers the anthers are generally loose and are well adapted to shed pollen on to the body of a hovering moth. The hawk moths, *Herse Convolvuli* and *Cephonodes picus* visit the flowers of many of the large flowered Ipomœas and the flowers of *Mirabilis jalapa*. The former is a very constant visitor, but the other one comes very rarely and it is extremely active and so rapid in its movements that it is impossible even to see it.

We have also plants that depend on water for pollination and they are all aquatic plants. The common water plant, Vallisneria may be selected as a type of plants fertilised by the agency of water. The flowers of this plant are unisexual and the plants are diœcious. Both the staminate and the pistillate flowers develop under water, and so, unless there is some special adaptation, fertilisation cannot take place. The male flowers are borne on short stalks almost at the base of the plant. At the time of flowering, or when the flowering season approaches, these get separated from their stalks and rise to the surface of water to float there. Simultaneously, the female flowers lying under water with spirally coiled stalks come up to the surface, in consequence of the uncoiling and growth of the stalk. The male flowers are most numerous and they float amongst the female flowers. The anthers open and the pollen is shed on the stigmas. In the case of flowers that are hermaphrodite, the flowers are raised above the water level, as in Nymphæa, so that they might be pollinated either by insects or by wind. It is only when flowers are unisexual and also submerged, pollination is effected by water currents. In all plants that are pollinated by currents of water the pollen grains are smooth, and pollination also is not a matter of certainty. So in these cases there is an abundance of pollen. During hot weather when water is low in ponds and

tanks we generally see masses of small white flowers floating freely on the surface.

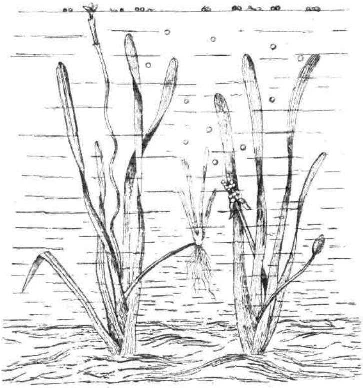


FIG. 226. *Vallisneria spiralis.*

Sometimes the aquatics which ordinarily raise their flowers above the water, do not do so when rain is heavy. Then the flower buds do not open and are then cleistogamic.

CHAPTER XIV.

FRUIT AND SEED.

SOON after fertilisation all the parts except the pistil wither and fall off, because they have done their work and are of no further use. But the pistil grows gradually and develops into the fruit. The process of fertilisation, besides transforming the ovules into seeds, produces other far-reaching results. The ovules before fertilisation remain enclosed in the ovary for protection, and even after fertilisation the need for protection is as great as before. Therefore, the wall of the ovary is also stimulated to growth by this process. The seed is dependent upon the placenta and the wall of the ovary for its food supply, and so the pericarp generally grows and becomes fleshy and sometimes even the placenta becomes so.

Although the fruit consists, in most cases, of only the seeds and the wall of the ovary, there are also fruits in which other parts become associated either forming an integral part of it or merely covering it. For instance, the style which almost always dries and falls off not only persists but also grows into a kind of feathery tail in Clematis and into a wing in *Ventilago madraspatana*. (See figs. 259 and 227.) The calyx often grows and envelops the fruit, as in Physalis and Withania. In the case of some fruits the receptacle becomes hollow with the ovary immersed in it in such a way that these two parts become fused into one; and this is the case in Guava, Pear, Apple and Cucumber. In all these fruits the edible fleshy part consists of both the pericarp and the receptacle. Instances are not wanting of fruits in which even the pedicels are implicated. The edible fleshy

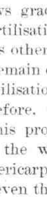


FIG. 227. Winged fruit of Ventilago. The style has developed in this into a wing.

portion in the fruit of Anacardium (Cashew-nut) is only the flower-stalk. (See fig. 231.) Even the floral axis of an inflorescence and the perianth are influenced so as to develop into fleshy structures and form an integral part of the fruit. We observe such changes in the fruits of Artocarpus and the Pine-apple (*Ananas sativus*). All these changes, occurring in parts, other than the pericarp, are not without significance; these changes are highly beneficial to the seeds, because they are helpful in protecting and dispersing them.

From all these considerations it is obvious that it is not an easy matter to define a fruit so as to include all kinds. For the sake of convenience and clearness, however, we define a fruit as a ripened ovary enclosing seeds instead of ovules. A fruit proper consists of only seeds and the pericarp; if other parts are found associated with the fruits we call them *false fruits*, *accessory fruits* or "*reinforced fruits*."

A fruit grows, becomes fleshy and may remain so until it leaves the parent plant, as in the case of the fruits of Mango, Guava, Brinjal and Tomatoes. In some cases it gets dry before leaving the plant, as is seen in Abutilon, Tridax and Castor. So it is customary to speak of fruits as fleshy and dry. The division of fruits into dry and fleshy fruits is purely artificial, and it is a matter of convenience. A fleshy fruit, dropping from one species of tree, and a dry one, detaching itself from another species of plant, are not strictly comparable, because they do not represent the same stage of development but belong to two different stages. A dry fruit long before it begins to dry (i.e., when it is fleshy) and a fleshy fruit are comparable, as then both of them are in the same stage.

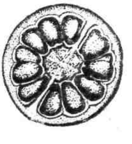


FIG 228. Berry of Solanum.

The necessity for some kind of classification of fruits arises, because there are so many different forms of fruits. The time-honoured division of fruits into dry and succulent kinds is as good as any other and so we shall deal with them.

Fleshy fruits.—We shall begin with the fleshy or succulent fruits; examples of fleshy fruits are furnished by such fruits

as the Brinjal, Grapes, Mango, Gourds and the Cucumbers. In all these fruits the pericarp is succulent and, except in the case of Mango, it is so throughout. But in the Mango the inner part of the pericarp is hard and stony. So we have to differentiate the fleshy fruits from one another and group them into distinct classes according to the nature of the fleshy pericarp. Fruits like Grapes or the Brinjal or Tomatoes, with pericarps that are fleshy right through their thickness, are called *berries*. We have in the Plantain, the Pomegranate, and the Guava berries. All these berries contain many seeds and they are fruits that do not open for setting the seeds at liberty. Seeds are allowed to get out by the gradual rotting of the pericarp or the fleshy pericarp may dry and then decay little by little thus setting them free. We have some berries, however, that dehisce, in Melons and Cucumbers ; we have also berries with single seeds and, as an example, we may mention the date fruit.

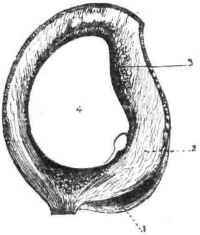


FIG. 229. Drupe of Mangifera. 1, epicarp ; 2, mesocarp ; 3, endocarp ; 4, seed.

There are fleshy fruits in which the pericarp is fleshy only outside, the inner part being hard and stony, as in the case of the Mango fruit. A fruit having this sort of modification in its pericarp is termed a *drupe*. In this type of the fleshy fruit the pericarp consists of three distinct layers, the outer surface skin *(epicarp)*, the fleshy middle portion *(mesocarp)* and the innermost hard stony part *(endocarp)*. Typical examples of drupes are furnished by the Coconut,

Almond and Zizyphus. The mesocarp in the case of the Coconut is fibrous, but in the others it is fleshy ; further, there is only one seed in the Coconut and the Almond, which is usually the case in most drupes, whereas in the third there are more seeds than one. There are instances in which the endocarp of a drupe, instead of forming one hard case for all the seeds as in Zizyphus, becomes divided into as many separate pieces as there are seeds. This is the case in the fruits of several Verbenaceous plants. Then, to differentiate such fruits from the drupes proper, they are called *pyrenes*.

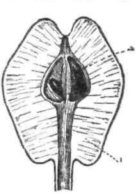


FIG. 230. Pome or fruit of a pear. 1, hollow receptacle ; 2, the pericarp.

Even in the case of berries we may speak of special varieties of berries. When the ovary is immersed in the hollow receptacle, the fruit that develops from it is called a *pome*. In these fruits the edible succulent portion is the hollow enlarged receptacle, and the parchment-like core enclosing the seeds is the pericarp. The Gourds and the Pumpkins have a thick epicarp and the placentas are parietal. This kind of fruit is called a *pepo*. Sometimes the pericarp happens to be leathery, as in limes and oranges, the fleshy part being hairs growing from inside the pericarp. These fruits are called *hesperidiums*.

FIG. 231. The Cashew-nut fruit.

Dry fruits.—Dry fruits have no food material in their pericarps when they leave the parent plant. These fruits generally open to liberate the seeds, if they contain numerous seeds. Some amongst the many-seeded dry fruits, instead

of bursting open, break into separate pieces, each piece corresponding to a carpel. Most of the single-seeded dry fruits do not open, and the seeds are set free by the decay of the pericarp. So we have both dehiscent and indehiscent dry fruits.

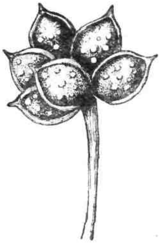


FIG. 232. Achenes of Ranunculus.

The fruits of Compositæ and grasses do not open, and so they are indehiscent dry fruits. In the fruits of Compositæ, the pericarp is thin and dry, and encloses only one loose seed. *Such fruits are called achenes.* Sometimes the individual carpels of an apocarpous ovary develop into single seeded indehiscent bits, as in Ranunculus, Clematis and Naravelia These also must be called achenes. Sometimes an achene-like indehiscent fruit possesses a wing, and, then it is called a *samara*. The fruits of *Hardwickia binata*, *Ailanthus excelsa*, *Holoptelea integrifolia*, and *Pterolobium indicum* are samaras. The grains of grasses and cereal plants look like seeds, but they are fruits in which the pericarp and the seed-coats have fused into one membrane and, therefore, the fruit looks like a seed. This kind of fruit is called a *caryopsis*.

FIG. 233. Samara of Hardwickia.

There are some fruits with many seeds that divide into as many parts as there are carpels. For example the fruits of Sida, Pavonia, Leucas, Heliotropium and Castor break into as many pieces as there are carpels. Such fruits are termed *schizocarps*. Each single segment is called a *coccus* and these in most cases contain a single seed. Again, these segments may remain indehiscent, or they may open to let the seeds out.

Next we have to deal with dehiscent fruits. The fruits of Calotropis, Vinca, Dregea, Wrightia and Sterculia consist

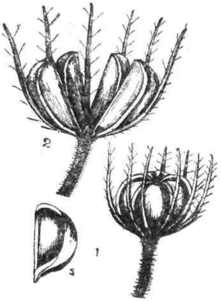


FIG. 234. Schizocarps of *Pavonia zeylanica.* 1, entire fruit ; 2, fruit breaking into its component segments ; 3, a segment or coccus.

of free carpels, and each of them opens along one margin, the one which bears the seeds (ventral suture). These fruits are called *follicles*.

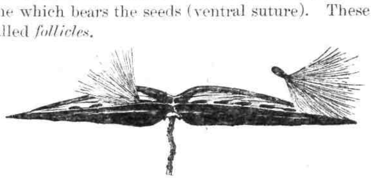


FIG. 235. Follicle of an Asclepiad.

Fruits of Crotalaria, Dolichos, Canavalia, Indigofera and Tephrosia are monocarpellary fruits, dehiscing along both the margins and they are called *legumes*. In some plants the legumes without opening by the sutures break into separate pieces, each one consisting of a bit of the pericarp enclosing a single seed. Such fruits are seen in some species of Desmodium and Mimosa, and they are termed *lomentum*.

When a dry fruit is the result of the development of a syncarpous gynæceum consisting of two or more carpels, and

at the same time if it liberates the seeds by dehiscence, it is called a *capsule*. This kind of fruit opens in various ways. For example those of Ionidium and Impatiens open by means of valves. The dehiscence in this case takes place longitudinally from the top to the bottom of the fruit, the pericarp breaking into distinct valves. This longitudinal dehiscence is sometimes partial, extending only to a small distance at the top of the fruit, as in *Argemone mexicana*. Amongst

FIG. 236. Legume.

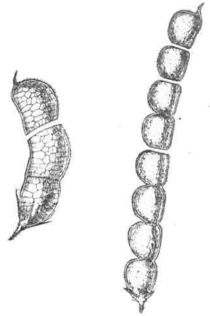


FIG. 237. Lomentum.

capsules there is variation as regards the cavities they contain. In Ionidium and Argemone there is but one cavity : but in the fruits of Hibiscus, Cotton, Corchorus and Aristolochia the locules are more than one. In the case of these fruits also the opening of the pericarp is longitudinal, but the position of the slit varies. Generally the slit appears in the pericarp along the dorsal sutures between the walls of division of the carpels, so as to expose the seeds. This kind of dehiscence is called *loculicidal*, and the fruits of Hibiscus, Cotton and Corchorus are capsules opening in this manner. Occasionally we come across fruits in which the slits appear along the lines of the junction of the carpels, i.e., through the septa or partition walls. In this case the seeds are not

exposed, until another opening takes place. This mode of dehiscence is well seen in the capsules of Aristolochia, and

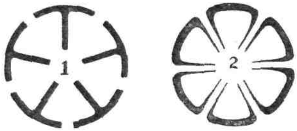


FIG. 238. Loculicidal (1) and Septicidal (2) dehiscence.

the dehiscence is said to be *septicidal*. The separation of the fruit into cocci in the case of schizocarps is the result of septicidal dehiscence. Sometimes, though rare, the pericarp breaks away from the septum just where it joins the partition wall leaving the septa as a column in the centre. This dehiscence is termed *septifragal* and it may be observed in the fruits of Datura. There are also fruits that dehisce transversely, the upper part of the capsule then coming off as a lid. The fruit then goes by the name of *pyxis*. The fruits of Portulaca and Trianthema are of this kind.

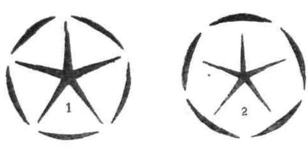


FIG. 239. Septifragal dehiscence. 1. septicidally and 2. loculicidally

A fruit resulting from the development of a single monocarpellary pistil or from a syncarpous polycarpellary ovary is a simple fruit. If the carpels in a fruit are quite free it is called an *aggregate* fruit.

The fruits of Polyalthia are aggregate fruits consisting of berries. In Clematis, Ranunculus and Naravelia the separate carpels are achenes ; and the aggregate fruit of Michelia

consists of free follicles. The Raspberry affords an example of aggregate fruit with *drupelets*.

As already pointed out in the earlier part of this chapter false fruits result from the fleshy development of the whole

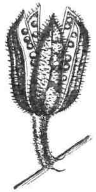


FIG. 240. Capsule of Hibiscus.

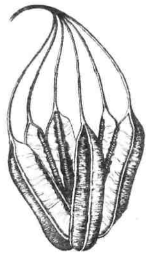


FIG. 241. Capsule of *Aristolochia indica*.

of the inflorescence. The Jack fruit and the Pine-apple are really spike-like inflorescences in which the stalks or axes, as well as the flowers, have become fleshy. The edible "flakes" in the Jack fruit are really flowers consisting of only perianth and the pistil. The succulent fleshy part is the perianth and the membranous bag enclosing the seed is the pericarp. From one side of the pericarp rises the style. These changes in the Pine-apple are still more marked. The polygonal areas seen externally in the case of the Pine-apple correspond to the flowers. The bracts and the withered remains of the other parts of the flower are often visible. But the lower parts of the flowers become fleshy and fuse with the axis.

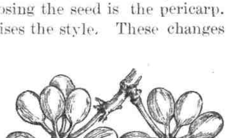


FIG. 242. Aggregate fruit of Polyalthia.

The fruit of the Banyan affords another example of the

inflorescence becoming a fruit. The succulent edible portion of the so-called fig-fruit is the hollow receptacle bearing male

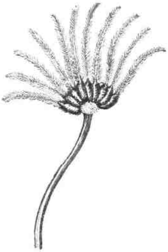


FIG. 243. Aggregate fruit of *Naravelia zeylanica*.

female and gall flowers. The so-called seeds are really so many achenes. All the species of the genus Ficus bear this kind of fruit and it is called *syconium* or *fig*.

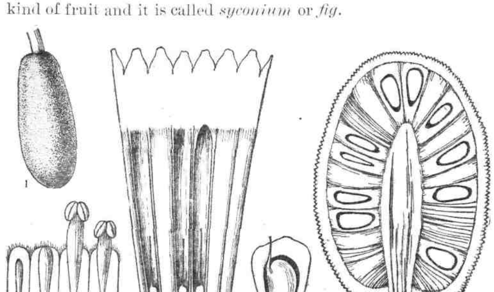


FIG. 244. The Jack fruit and its parts. 1, male spike; 2, male flowers; 3, female flowers; 4, young fruits in spike; 5, young fruit with its fleshy perianth.

We have already dealt with the structural details of a few seeds. We know that a seed is after all a young plant wrapped up in the seed-coat and that flowering plants usually reproduce themselves by means of seeds. As the embryo within the seed remains dormant until the time of germination, we may say that the life of a flowering plant is divided into two periods one short and the other long. The period

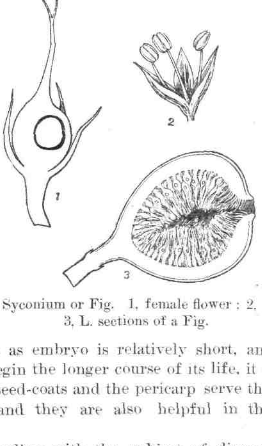


FIG. 245. Syconium or Fig. 1, female flower; 2, male flower; 3, L. sections of a Fig.

of life spent as embryo is relatively short, and until it is allowed to begin the longer course of its life, it needs protection. The seed-coats and the pericarp serve the purpose of protection, and they are also helpful in the matter of dispersal.

Before dealing with the subject of dispersal of fruits and seeds we shall refer to the structure of seeds once more. The essential parts of a seed are the embryo and the enveloping seed-coats; and in most cases we do not find any other part. The embryo itself consists of the primary axis and the cotyledons which usually contain the food reserve. Such seeds are called non-endospermic seeds. In seeds of some plants the reserve material remains outside the embryo, but within the embryo-sac. This reserve stuff is called endosperm and, therefore, seeds

having endosperm are called endospermic seeds. In the case of the non-endospermic seeds all the food material is absorbed and stored up in the cotyledons as the seed ripens.

In some genera of Leguminosæ even in the fully matured seeds, a small quantity of endosperm is seen to persist, thus forming a link as it were between the endo-and non-endospermic seeds, whereas in the endospermic seeds the reserve material is not transported into the cotyledons, and it is gradually absorbed only during germination. The fact that the reserve material is transferred from the endosperm into the cotyledons becomes obvious if we examine the seeds of several legumes in the course of development. In partially developed seeds of Cassia, Dolichos, Crotalaria, etc., we find the cotyledons embedded in a fleshy mass which is massive in very young seeds and it gradually decreases and the cotyledons increase in proportion. The nucellus of the ovules that are destined to become endospermic or non-endospermic seeds is absorbed gradually and when the embryo is fully formed nothing of the nucellus is left. But there are some plants in which a portion of the nucellus persists and remains as a portion of the seed. For instance in the seed of the pepper fruit the small embryo is surrounded by a small quantity of endosperm, and the bulk of the seed consists of something lying outside the embryo-sac, though inside the seed-coats. This stuff lying outside the *embryo-sac* is termed *perisperm*. Many plants of the order Piperaceæ and some Nymphæas have seeds with perisperm. In the case of Canna also the seeds contain perisperm.

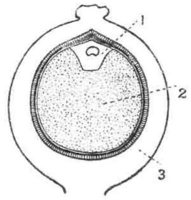
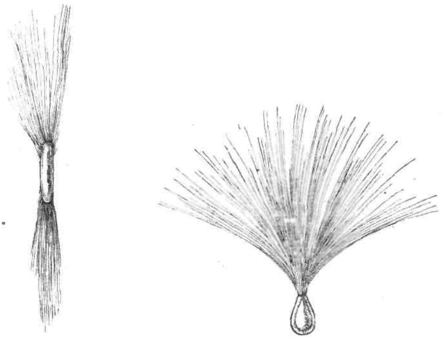


FIG. 246. Piper fruit. 1, endosperm; 2, perisperm; 3, pericarp.

The seed-coats are in most seeds smooth and there is considerable variation in their colour. Besides this we find outgrowths on the testa, either in the form of wings or hairs. In the seeds of Asclepiads and some Apocynes there is a tuft

of hairs at one end of the seeds, and in some even at both ends. There are also seeds whose testas are fully covered with hairs, as in Cotton, *Hibiscus micranthus*, *Eriodendron anfractuosum* and *Cochlospermum Gossypium*.



A B

FIG. 247. Comose seeds. A, Alstonia seed : B, Calotropis seed.

Fleshy or membranous outgrowths from the funicle or the micropyle are found in several seeds, and these outgrowths are called *caruncle*, *strophiole* or *aril*, according to

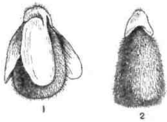


FIG. 248. Strophiole of Polygala seeds. 1, seed of P. chinensis ; 2, seed of P. elongata.

their origin and size. We have such appendages in Castor, Polygala, Nymphæa, Modecca, *Pithecolobium dulce* and *Myristica fragrans*.

All seeds possessing two cotyledons are called dicotyledonous seeds, and those with a single cotyledon as typified by the caryopsis and the Date seed are monocotyledonous seeds. All monocotyledonous seeds are endospermic. In all endospermic seeds, whether dicotyledonous or monocotyledonous, the embryo is much less developed than it is in non-endospermic seeds.

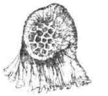


FIG. 249. Aril of the seed of Modecca.

For example, the embryo in the Date seed is a very minute body, found on one side of the stone in a small pit. The stony part is the endosperm.

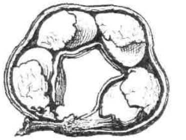


FIG. 250. Aril in *Pithecolobium dulce.*

FIG. 251. Aril of Myristica.

For the sake of clearness and convenience we may classify the seeds somewhat as follows :—

A.—Monocotyledonous seeds (seeds with a single cotyledon).

All monocotyledonous seeds are endospermic and the cotyledon never comes out.

B.—Dicotyledonous seeds (seeds with two cotyledons).

(*a*) *Non-endospermic*—the seed consists of the primary axis, the cotyledons and the seed-coats.

(*b*) *Endospermic*—the seed consists of the primary axis with the cotyledons, endosperm and the seed-coats.

(*c*) *Perispermic*—the seed consists of the embryo endosperm and also perisperm. This kind of seed is rather rare.

C.—Fruits that look like seeds—

There are many plants whose fruits look like seeds, and ordinarily they pass for seeds. The caryopsis of cereals and the achenes of Compositæ pass for seeds. But a close examination of these "seeds" will reveal the fact that they are really fruits and not seeds. Seeds as a general rule never appear naked and are never exposed at any stage, except by the bursting open of the pericarp. Further, the seeds are always attached by their stalk, and, therefore, there will be only a single mark of detachment or scar. Fruits, on the other hand, have two scars, one, the point at which it was attached to the receptacle, and the other, the style scar.

CHAPTER XV.

FRUIT AND SEED DISPERSAL.

A flowering plant brings into existence seeds by a considerable expenditure of material manufactured by it. Mere production of seeds counts for nothing, unless they are given chance to get themselves established in suitable localities. It is a matter of common observation that most plants produce seeds far more than what can reasonably be expected to germinate and grow. If all the seeds of a plant were to fall below it or even in its proximity, there is sure to be an intense struggle as soon as they all germinate. On account of the overcrowding, a very large number of the seedlings are not likely to get enough food and air, and all but the very strongest would ultimately die. The struggle in this case is very severe, because all the individuals are alike in their mode of growth and all need, more or less, the same kind of food. Even the few sturdy seedlings that survive the struggle cannot be expected to do well, because the soil and other conditions are not likely to be very favourable. If the plants are to grow strong and become sturdy, it is essential that each seed should find a place where it will have plenty of room to grow, besides sufficient air and sunshine. This is possible only if the seeds are scattered far and wide. A seed, in order to have the best chance to grow, must find a place far removed from its fellows. If it is able to do this, its chances of growing to maturity are very great, and the continuance of the species is also thereby ensured.

The distribution of seeds is essential for the proper development of the individual plants, as well as for the maintenance of the species. Flowering plants are rooted to the soil and are unable to move. Yet we see plants of the same species growing far and wide and some species are found distributed all over the world. This is undoubtedly due to the wide distribution of the seeds of plants, and for dispersal the seed stage of the plant is best suited ; the embryo lies dormant, and its vitality being suspended it can withstand changes in its environment.

As already mentioned, plants are capable of producing seeds in large numbers. In spite of the prolificity of most plants in the matter of seed production, in nature we do not see any one species developing and occupying considerable areas to the exclusion of others, except under very special conditions. Even plants producing a small number of seeds would occupy a very large portion of the earth in a few years if all the seeds produced in successive generations were to grow successfully into plants after germination. The great naturalist Linnæus has made out by calculation that a plant producing only two seeds in a year will number over a million in twenty years, if all the seeds that are produced in every successive generation are capable of growth. This estimate is very low and does not give us an adequate idea of the rapidity with which a species is able to spread. Ordinarily plants produce a very large number of seeds. A Tobacco plant for instance produces from 300,000 to 350,000 seeds: *Argemone mexicana* from 20,000 to 25,000 seeds. According to Kerner if a Henbane plant producing on the average 10,000 seeds a year were allowed to grow undisturbed and, if all the seeds produced each year, is capable of full development, the whole of the dry land would be occupied at the end of five years. Another plant Sisymbrium which produces 730,000 seeds a year would occupy an area 2,000 times as great as the surface of the dry land in the course of three years.

Considering the risks to which the seedlings are exposed and the deaths taking place in the competitive fight, the overproduction of seeds becomes a sheer necessity. The struggle is so fierce and the dangers to which these are exposed are so formidable that one is justified in wondering how even a few have survived. But, for the maintenance of the reasonable average number both as regards the individuals and the species, the overproduction cannot but be a distinct advantage. Another advantage is that the species is likely to spread to new spots that are favourable. Even if many succumb in the struggle a few at least are likely to fall in situations remote from the parent and such situations are always good for them. It is a well established fact that occasional driftings to different surroundings act beneficially in stimulating the plants to good growth.

There are other considerations regarding the seed that are also of very great importance in this connection. The success or failure of a plant to become well established depends, to a certain extent, upon the amount of reserve food material existing in a seed. Some seeds as in the Coconut are large and there is a large quantity of food stuff available for the young plant. So it can make use of it, until it is able to prepare its own food. When seeds are massive the production of seeds is by no means large, numerically. If, on the other hand, the seeds are small the number produced by a plant ought to be very large, because the food carried by the seed for the embryo is very limited.

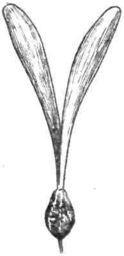


FIG. 252. Winged fruit of Gyrocarpus.

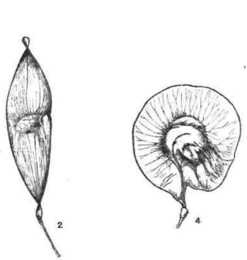


FIG. 253 Fruits with wings. 2. Ailanthus, and 4. Pterocarpus.

Just as we find variations to a large extent in other parts of plants, we meet with very great amount of variation in fruits and seeds also. For instance we find seeds so small that we could hardly see them with the naked eye, as in Orchids and Striga ; and we also find massive seeds as in the Coconut and seeds of all dimensions ranging between these extremes. Again as regards colour also we find a great range in variation. In the matter of structure and appendages it is equally so. These variations in different directions cannot be a matter of mere accident, and they must have some significance. The significance becomes obvious, if we bear in mind the sheer necessity for the wide dispersal of seeds. Without

special adaptations and special agencies, dispersion is a matter of difficulty. Variation in all directions is a positive advantage.

Let us now consider some examples of fruits and seeds and see if all that is said of them is true. The fruits of *Gyrocarpus Jacquini*, a common tree of the plains, are interesting. This fruit consists of a round or ovoid portion enclosing the seed and two long wings varying in length from two to three inches. (See fig. 252.) During the hot weather this tree bears heavily. Whenever there is a wind, a large number of fruits are detached and they are wafted in the air. They are carried to long distances, because the fruit does not fall down as long as the wind lasts. On account of the wings the fruits keep on spinning round and round like a top or a shuttle-cock shot in the air. The relation existing between the spread of the wings and the size and weight of the seed is such that it is capable of sailing in the air for sometime at least, before it comes down. On one occasion the fruits of this tree were found nearly a mile away from the tree. From this example we clearly see that winged seeds are specially meant for dispersal by wind. We have in this presidency many examples of winged fruits, and all of them belong either to trees or lofty climbers. The possession of wings in the case of winged seeds of trees is not a matter of mere accidence. It is developed solely as a means of dispersal. If the presence of wings were accidental and the dispersal merely its result, we should expect to find winged seeds in all kinds of plants. For instance, we should have such seeds in the case of even low herbs, and aquatics. We do not of course come across winged seeds on low herbs, because they would obviously be of no use. Though the winged seeds of trees are capable of sailing high in the air, they cannot do so low down, and some height is necessary. As they are usually heavy they cannot be lifted from low situations for want of enough force on the part of the wind. We know that the force of the wind goes on increasing with the height. In the case of tall trees the height is an advantage, because the winds are likely to blow more strongly there and the seeds are not likely to be impeded in their travel and they escape being entangled.

Of the numerous winged fruits occurring in the flora of this part of India, those of Ailanthus, Holoptelea, Combretum, Pterocarpus, Pterolobium, Hardwickia, Hopea, Shorea and Dodonæa are common enough. As examples of seeds with wings we may mention the seeds of Cedrela, Soymida, Tecoma, Dolichandrone, Oroxylum and Mahogany.

FIG. 254. Winged fruits of 1, Combretum and 3, Pterolobium.

From the fact that winged seeds are confined to trees it must not be supposed that herbs do not make use of the wind for dispersal of their fruits or seeds.

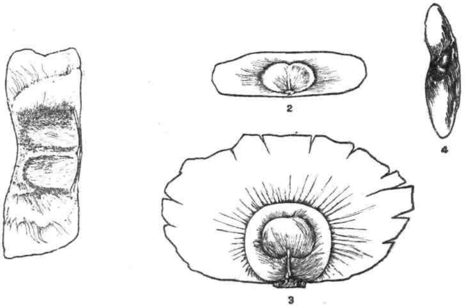


FIG. 255. Winged seeds of 1, Dolichandrone ; 2, Tecoma ; 3, Oroxylum and 4, Cedrela.

Just as wings are specially good for seeds of trees so plumes are best suited for low herbs and shrubs. The parachute-like pappus hairs of the Tridax achenes are far more

efficient for their dispersal than wings. For lifting the fruits from low situations the plume is the best possible adaptation. It is this appendage that has enabled the plant Tridax to

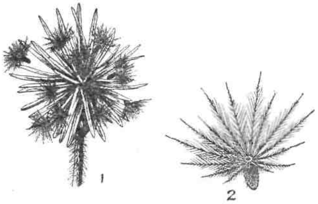


FIG. 256. Pappus bearing achenes of *Tridax procumbens*. 1. flower head with achenes : 2. a single achene.

establish itself everywhere. This plant was introduced into this country some years ago and within a short space of time it has managed to spread everywhere. It was not at all common at higher altitudes some fifteen years ago and now it is as much at home there as it is on the plains. Examples of plumed fruits and seeds are afforded in abundance by the families Compositæ and Asclepiadeæ and also Apocynaceæ. We all know that plants of these families are very widely distributed and we find some species or other of them almost everywhere. The plume or hairs are from the calyx in the case of the achenes of the Compositæ ; but in the case of the Asclepiadeæ and Apocynaceæ it is the seeds

FIG. 257. Plumose achenes of *Vernonia cinerea*

that bear the tufts of hair (see fig. 247); so also is the case with the Cotton seed and that of Hibiscus micranthus. Clematis furnishes examples of achenes whose styles are not only persistent, but are also provided with hairs to facilitate their dispersal. Both in winged and plumed fruits we generally find only one seed.

We have several plants possessing small seeds with special devices to bring about dispersal. The seeds are numerous in such plants, and they lie loose at the bottom of a capsule which is usually borne at the ends of stiff upright elastic peduncles. Every gust of wind will shake the fruit, and on account of the stiffness of the stalk there will be a sudden rebound to the original position which must lead to the scattering about of some seeds at least. Capsules, intended to shed their seeds thus, open only at the top either by means of pores or by very short longitudinal slits. This arrangement prevents the shedding of all the seeds at once and in one place. Winds do not blow always with the same force and so the seeds have the chance of falling in different places. The introduced Mexican poppy, *Argemone mexicana*, is an excellent example to illustrate this fact. The single-celled capsules of this plant are at the extremities of stiff branches and the dehiscence is by means of short slits at the top. The seeds are small and every time there is a wind a few seeds are shot forth, sometimes near and at other times a little farther, according to the nature and force of the wind.

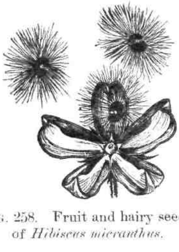


FIG. 258. Fruit and hairy seeds of *Hibiscus micranthus*.

When a solid round body begins to decrease in volume its surface will also diminish relatively to the mass, but the rate with which the volume decreases is greater than the rate of the diminution of the surface. So a body when it reaches a certain point of smallness the surface that it possesses in relation to its weight will be proportionately more, than when it is larger. The seeds of Orchids are very small

and they have sufficient surface to enable them to remain in air sufficiently long. And when winds blow, such seeds may travel very long distances.

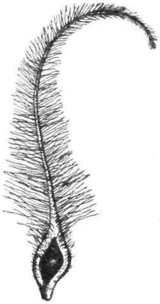


FIG. 259. Achene of Clematis.

FIG. 260. Capsule of Argemone.

Several dry fruits scatter their seeds to long distances by *their bursting*. The fruits of Canavalia and those of several other leguminous plants hurl their seeds to long distances by the sudden breaking of the valves and their twisting in the opposite directions. The seeds of Canavalia are hurled to a distance of ten to fifteen feet when the valves of the fruit burst open. The cocci of the Castor fruit are also thrown several feet when the fruit

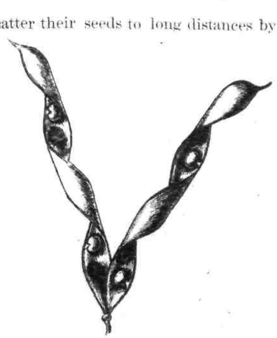


FIG. 261. A legume bursting and hurling its seeds,

dries and breaks. Euphorbias scatter their seeds in the same manner. The fruits of *Hura crepitans* burst with a noise almost as loud as the report of a chinese cracker. As further examples of fruits that expel their seeds by explosion we may mention those of Impatiens and of some species of Acanthaceæ. The fruits of *Ruellia prostrata* have at their tips a specialised spot which when wetted leads to the sudden bursting of the capsules. If we place these capsules in water, as soon as the tip becomes wet they burst with a noise scattering the seeds on all sides. We can feel the force with which it bursts, by putting these capsules into our mouth.

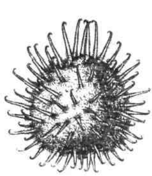


FIG. 262. Hooked fruit of *Triumfetta rhomboidea*.

We have now to consider those fruits that are provided with hooks and spines. These are undoubtedly meant for dispersal by animals. The fruits get entangled in the fur of animals, by means of the hooks. If we examine our clothing, after a ramble through a scrub or a waste place, we find many kinds of fruits sticking on to them. The fruits that commonly stick on to our clothes thus are those of Achyranthes, Pupalia, Triumfetta, Zornia and Desmodium. Amongst herbs and shrubs there are many plants that bear hooked fruits. The fruits of the plants Urena lobata, U. sinuata, Xanthium strumarium, Bidens and Mimosa are also hooked.

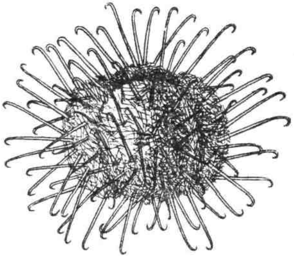


FIG. 263. Hooked fruit of *Triumfetta pilosa*.

In all these cases the hooks are small and they are directed on all sides. As most of these fruits are small, they do not seem to cause any inconvenience to the animals to whose skins they cling. A most remarkable example of a hooked fruit of a formidable nature is mentioned by Sir John

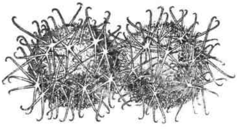


FIG. 264. Hooked fruits of Pupalia. The hooks are imperfect flowers.

Lubbock. The South African genus Harpagophytum produces fruits that are really formidable on account of the woody spines borne by the pericarp of the fruit. These

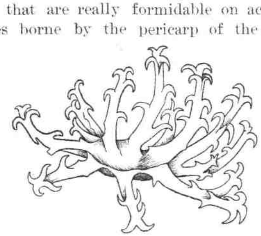


FIG. 265. The fruit of the Grappling plant (after Lubbock).

spines called "grapples" are woody and are about an inch long, and are provided with barbs turned in various directions. These fruits are said to roll about and become attached to the skin of lions. The unfortunate animal in its attempts to get rid of this fruit, sometimes gets it into its mouth and then it dies.

The hooks or spines are developed from various parts. In the fruits of Urena, Triumfetta, Zornia and Cullenia the hooks arise from the pericarp.

In Bidens the pappus horns are barbed. In some cases the perianth persists along with the fruit, and the tips

of their lobes are spinescent, as in Achyranthes. Sometimes imperfect flowers become hooks as in Pupalia. Even bracts sometimes develop into hooks as in *Tragus racemosus*, or these are spinescent as in *Amarantus spinosus* and *Echinops echinatus*. In the case of *Xanthium Strumarium* the achenes are enclosed by the involucral bracts and these bear hooked spines. This plant is really a troublesome weed, as it spreads widely and rapidly. In South Africa the fruits of Xanthium are said to have caused so much damage to the wool, some years back, as to necessitate a legislation to extirpate this weed. Even in this country it sometimes monopolises large areas, especially wet clayey situations and then it is not easy to get rid of it.

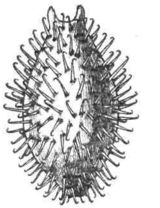


FIG. 266. Fruit of Xanthium.

We have also a few species of plants producing sticky glands which help the fruit in their dispersal by sticking to the feathers of birds. We have such fruits in Pisonia, Boerhaavia, Siegesbeckia and *Plumbago zeylanica*.

The dispersion of hooked and sticky fruits is brought about by the agency of animals, and the animals do not do this consciously. But in the case of fleshy fruits, animals deliberately go in search of them and eat them. As already pointed out, the seeds in the fleshy fruits are all hard, if the fruit is a berry, and the hardness is due to the thickening of the seed-coat. If they are drupes then the seeds remain within the stony endocarp. In both these cases the seed possesses an indigestible covering. Around the hard covering is the sweet

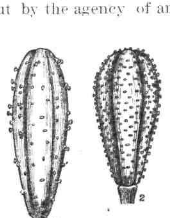


FIG. 267. Boerhaavia fruits. 1, fruit of *B. repanda*; 2, fruit of *B. repens*.

luscious edible fleshy part. All fleshy fruits are highly coloured, after the seeds are fully formed and ready for dispersion. But in young and unripe fruits the pericarp is generally green and the fleshy part will invariably be very unpalatable. Fruits get their characteristic colour only when they are fully mature and ripe. The distribution of unripe fruits is in no way beneficial for the plant, and as a safeguard against this sheer waste the fleshy part remains unpalatable, until the seeds are fully developed and are ready for travel. This mode of dissemination is very common and it must rank very high among the different modes of dispersal and is second only to dispersion by wind.

Some seeds get dispersed on account of their arils, or strophioles. The seeds of *Pithecolobium dulce* have very well developed arils which are sweet when the seeds are mature. Then birds peck at the aril and devour it dropping the seed in various places. (See fig. 250.)

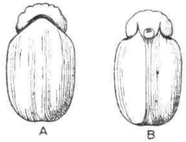


FIG. 268. Jatropha seed. A, back and B, front view.

There are some seeds which depend for their dispersal on deceptive appearances. They resemble insects and are consequently picked up by certain insectivorous birds, but only to be thrown away as being useless, and this is exactly what the seeds need. Instances for this type of seed are provided by the Castor and Jatropha seeds.

We have instances of plants securing dispersal by the whole of the inflorescence being carried by the wind over long distances. The seashore grass *Spinifex squarrosus* is disseminated by its large round ear-heads that roll along the ground with the winds.

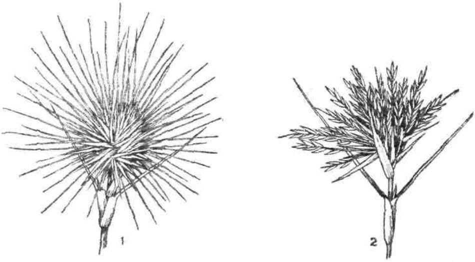


FIG. 269. The inflorescence of Spinifex.
1, female ; 2, male.

Lastly, we have also fruits depending on water for their dispersal. As examples, we need only mention the Coconut, the Seychelles Double Coconut, the top-like receptacle of Lotus which carries the fruits, the fruit of *Cerbera Odollam* and that of *Entada scandens*.

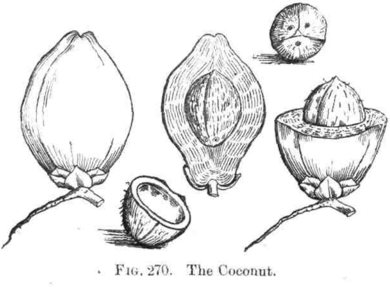


FIG. 270. The Coconut.

CHAPTER XVI.

VEGETATIVE REPRODUCTION.

REPRODUCTION is a most necessary process in the life of a plant and for most plants the production of seed is of paramount importance, for without it the extension and distribution of species is well nigh impossible. In the case of higher plants the obvious method of propagation is by means of seeds that are produced by sexual reproduction, a process very complex in character, in as much as it involves the fusion of very specialised cells called *gametes*.

It must not be thought that this is the only method by which plants multiply and get dispersed. Instead of always adopting this most complicated form of propagation, plants sometimes have recourse to other modes of reproduction. There are many ways by which they reproduce themselves, in all of which the fusion of the gametes is dispensed with and only portions of the vegetative organs are concerned. These processes are simple in character and are merely the results of growth. Hence all these processes go by the name, *Vegetative Reproduction.*

We all know that some plants are propagated by means of small bits of stems. For instance the plants *Clerodendron phlomoides, Convolvulus arvensis, Cynodon dactylon* and a host of other plants propagate themselves in this manner. These plants have an extensive system of underground stems that are very brittle. Even small bits of these branches are capable of growing into separate plants. It is this special feature of these plants that makes them most troublesome weeds. We have many species of plants that propagate themselves vegetatively, even in a wild state. Many plants have lost the power of producing seeds under cultivation, and consequently they can be propagated, only by vegetative reproduction. The methods of vegetative propagation are as varied, as are the means for the dispersal of seeds.

Plants having a creeping habit similar to that of *Hydrocotyle asiatica,* flourish everywhere. In all such plants

branches creep along the surface of the ground producing roots at the nodes. These plants may go on increasing and establishing new colonies in any number and occupy within a short time considerable areas, because of the capacity of becoming independent plants possessed by the creeping branches, when they get severed from the older portions either by decay, or accident.

FIG. 271. *Convolvulus arvensis*, L., showing the underground stems

There are many plants whose stems are mostly subterranean and the main work of these underground stems may be said to be the propagation of their kind. Subterranean stems in which reserve food material is stored in abundance, such as, rhizomes, corms and bulbs, are specially adapted to serve this purpose. The underground branches, like other organs of a plant, vary very much in their form and structure. There are plants whose underground stems differ very little from the ordinary aerial branches. For instance, in the Hariali grass, the stolons are white, bear adventitious roots and have scale-leaves instead of green foliage leaves. There is no visible storage of food material. In the grass *Panicum repens*, we have an example of a plant whose underground parts consist of both stolons and rhizomes. Several species of Cyperus develop stolons, as well as tubers or bulbs. Instances there are in which the whole of the shoot-system consists of rhizomes. Further modifications are the bulbs, tubers, and corms. All these modifications are undoubtedly due to the storage of reserve food material.

When the underground stems are stoloniferous or rhizomic in character some of them turn up, come above the

surface and develop into ordinary leafy branches. These aerial branches remain connected with the underground stems and depend upon them for their development, until they become fully established. When once these aerial branches have become fully established, they are capable of becoming independent plants. On account of the continued connection and the presence of roots storage of reserve food becomes unnecessary in these cases. From the underground stems large number of branches may come up, but amongst them those developing from the terminal bud and lateral buds in its proximity are usually more vigorous than those arising from the lateral buds lower down.

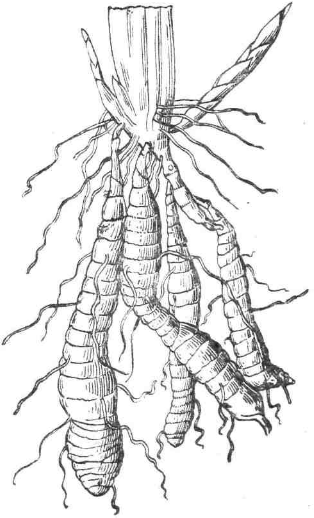


FIG. 272. Rhizomes of Arrowroot.

Now coming to the very much modified stems, tubers, corms and bulbs these are much better fitted for vegetative propagation than rhizomes and stolons, as the abundant storage of reserve food is a positive advantage to start their growth. In these cases the separation from the main plant may take place long before the appearance of the daughter plants.

As an example we may mention the Potato. In the Potato plant some branches develop underground, grow and

become thickened at their ends forming tubers. These tubers are capable of growing into separate plants when detached from the parent plant. Sometimes and in some plants the axillary buds in the aerial branches develop into aerial tubers. For instance in many cultivated species of Dioscorea aerial tubers are very common. They all drop down and then grow into separate plants. In Agaves and Chlorophytums bulbils appear in the inflorescence, and they drop down and develop into separate plants.

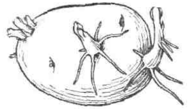


FIG. 273. Potato tuber germinating.

A corm, as for instance in Amorphophallus or Synanherias, represents the whole of the shoot system of the plant. The reserve food material, instead of being stored in the lateral branches, is allowed to accumulate in the main stem, and the lateral branches remain as small buds on the surface of the corm. All the buds found in a corm are capable of developing into new corms in their turn, although it is the terminal bud which usually grows and becomes the new corm. Generally corms of two or three seasons remain together. (See figs. 97 to 99.) In the corm of Amorphophallus there are no scale-leaves; but sometimes a corm may be covered by a few scales, or the scales may be many and the stem also somewhat massive, as in the tuberose, making it intermediate between a bulb and a corm. Such structures as these go by the name "Solid bulbs" amongst horticulturists. From this to the bulb proper is an easy gradation. In a bulb the axis is not very conspicuous and

FIG. 274. Polianthes. Note the daughter bulbs.

the scales are numerous. In bulbs, whether solid or ordinary, we find many daughter-bulbs,—really axillary buds, and by these they get multiplied. (See figs. 274 and 275.)

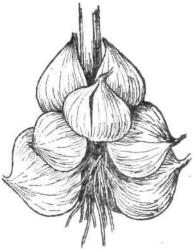


FIG. 275. Onion bulbs.

In rare instances even leaves give rise to buds which usually develop into plants later on. Adventitious buds develop at the margins of leaves of *Bryophyllum calycinum* and in *Scilla indica* at the apex of the leaves. When injured, buds make their appearance in the leaves of Begonia.

Even roots, as has already been mentioned in another chapter, are capable of producing shoots when cut. This affords another means of vegetative propagation.

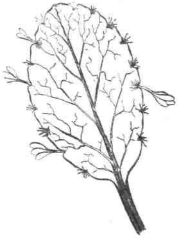


FIG. 276. Bryophyllum leaf with adventitious buds.

In addition to the various methods of vegetative reproduction, many a plant, still possesses the power of regenerating the parts that are lost. This tendency is taken advantage of in the propagation of rare and valuable varieties of plants. It is this property that makes it possible to raise plants by grafting, by layering and by means of cuttings.

Very often one comes across plants that are able to propagate themselves by the production of seeds, as well as by the vegetative method of reproduction, by the one or the other of these two methods according to circumstances. It may be that the plant is capable of bearing seeds in abundance and yet it sometimes may adopt the vegetative method of reproduction.

From this it is clear that there should be certain factor which determine the kind of reproduction to be adopted by the plant, when it is capable of both sexual and asexua reproduction. From experience we know that all the conditions favouring large accumulations of food stuff and vigorous growth tend to make a plant grow vigorously and develop its vegetative parts. And then such a plant tends to multiply itself by vegetative reproduction. When conditions are not favourable for a vigorous growth, plants resort to the formation of seeds. We often see plants growing in open dry places running into flower and seed.

The effect on the offsprings of a plant produced by reproduction will vary with the kind of reproduction. If the offsprings have resulted from vegetative reproduction, they will maintain the characteristics of their parent plant. The vegetative method of propagation will, therefore, enable any one to propagate a variety or form without any change in its character, and make it occupy the land quickly. But, it must be remembered that plants produced by vegetative propagation are less able to withstand changes in their environments, than those derived from seeds. With plants produced by the sexual method, it is far otherwise. In this case the fusion of cells from two different individuals, which is the chief feature of this process, changes the character of the offsprings in a profound manner. Generally the offsprings differ from their forbears in some respects at least. Some of the offsprings may be like one parent, some like the others and some others may differ from both. No doubt the young plants may resemble the parents in a general way, but on close inspection differences also will become apparent. This tendency is an advantage, if new varieties are required, and in nature it leads to the formation of new plants. To make this point clear we may take the case of propagation of mango. If one wishes to have Mango plants of a particular variety in large numbers, he should adopt the vegetative propagation, but if the object is to obtain different varieties he must have recourse to seeds that result from sexual reproduction.

CHAPTER XVII.

PRINCIPLES OF CLASSIFICATION.

AMONGST plants, the spermatophyta or seed-plants represent the most highly organised group. It includes a very large number of individuals (about 120,000 now), with an endless variation in their structure and mode of life. To get an insight into the forms of plants that exist, some sort of grouping of plants or classification is necessary, otherwise it is impossible to make any progress in acquiring the knowledge of plants.

By comparing plants with one another we find resemblances as well as differences, in varying degrees, and it is usual to speak of the resemblances as *affinities*. It is obvious that plants which are alike in several characters should have had a common origin. For example, the individual plants of a crop are all alike in many respects, because they are the offsprings of one kind of plant. So affinities show the *relationship amongst plants*.

The earliest system of classification which was in use until the middle of the last century, is the Linnean system of classification based upon the single characteristic, the number of the stamens in a flower. This system, though most convenient for practical use, is defective and unsatisfactory, because of its arbitrary and artificial nature. When plants are grouped, taking into consideration only a single character, we are obliged to bring together plants having no real affinities and keep apart those closely related. The Linnean system is now superseded by others, more natural because a larger number of characters form the basis for classification. The main aim of the modern systems of classification is to express the relationship between different plants. Therefore, as many characters as possible are taken into consideration. And it is only then, that the exact relationship could be determined.

There are two Natural systems of classification now in use, and they are (1) the system of Engler and (2) the system

of Bentham and Hooker. The former is largely in use on the continent of Europe, while the latter is the standard one in Great Britain and India. Therefore, in this chapter we shall follow Bentham and Hooker's system.

Flowering plants with a closed seed vessel or Angiosperms are divided into *Dicotyledons* and *Monocotyledons*.

Dicotyledons, as the name implies, have two cotyledons in their seeds. Flowers are generally tetra-or pentamerous and the leaves are net-veined. A well marked tap-root and a stem with secondary growth are also the characteristics of this class.

Monocotyledons, on the other hand, have only one cotyledon in their seeds. Flowers are trimerous and leaves are parallel-veined. The stem, as a rule, does not increase in thickness and there is no tap-root.

These classes are further subdivided into sub-classes, *Series* and *Natural Orders* or *Families*, as shown towards the end of this chapter.

For purposes of classification plants of a particular kind are said to be of one *species* and species are grouped together into a larger group, the *genus*; and the genera are further grouped into *Families* or *Natural Orders*.

We shall try to render all these points quite clear by means of certain examples. Let us select a common plant such as the Bendai or the Okra plant. All the plants raised from the seeds of a Bendai plant are of the same kind and so we consider this kind to be a *species* and the scientific name of this species is *Hibiscus esculentus*, L. On comparing this plant with three other kinds or species, Gogu, Shoe-flower and *Hibiscus vitifolius*, L., we find that all these species are similar in certain characters, especially in the parts of the flower. These common characters are as follows:—The stamens form a monadelphous tube, with kidney-shaped unilocular anthers, enclosing an inferior ovary and a filiform style which ends in five stigmatiferous branches; petals are five, free, contorted and adherent at the base to the staminal column; and the calyx is monosepalous with an epicalyx of bracts at its base. These characteristics constitute the diagnosis of a genus and so all plants possessing the above characteristics should be brought under this genus, and the

name of the genus is *Hibiscus*. These four plants that we have chosen as examples belong to the same genus, Hibiscus. We have about a dozen species under this genus growing in this part of India. The scientific names of the plants, Bendai, Gogu and Shoe-flower are respectively *Hibiscus esculentus*, *Hibiscus cannabinus* and *Hibiscus Rosa-sinensis*.

We have a number of other plants resembling the *Hibiscus* in certain features. For instance, the Portia tree, the cotton plant and the plant *Abutilon indicum*, G. Don., resemble the *Hibiscus* in certain respects. All these plants agree with the genus *Hibiscus* in having a staminal tube with unilocular anthers, free contorted petals, adnate with the staminal column at its base and a monopetalous calyx. On account of these common characteristics we are justified in grouping all these plants, as well as the species of *Hibiscus* mentioned above, under one higher group, the Family or the Natural Order. The name of the Natural Order, in this case, is *Malvaceæ*.

It would, perhaps, conduce to clearness, if we set forth all these facts in a tabular form so as to indicate the limits of species, genus and the Natural Order—

All plants having flowers with monosepalous calyx and free contorted petals, adherent at base to the staminal tube with unilocular anthers belong to the *Family*, *Malvaceæ*.	*Malvaceæ*.

Plants of the family Malvaceæ may further be subdivided into *genera* and *species* as shown below :—

Style branched at the free end—

Epicalyx present—

bracts five or more ... ... style branches five ... ... ovary five-or many-celled ...	*Hibiscus*.
bracts three ; style lobes three ; ovary three-or four-celled.	*Gossypium*.

Epicalyx not present—

style branches and cells of the ovary twenty or more.	*Abutilon*.

Style not branched at the free end. *Thespesia*.

The species of the genus Hibiscus.

Flowers, large, showy—
  Petals yellow—
    fruit small, angled sharply, seeds naked : } *H. vitifolius.*
    fruit small, but with close-set harsh bristles ; calyx with glands outside. } *H. cannabinus.*
    fruit long ; calyx spathaceous ... *H. esculentus.*
  Petals red—
    fruit not formed ... ... *H. Rosa-sinensis.*
Flowers, small—
  Petals white—
    fruit small and round : seeds cottony. } *H. micranthus.*

SYSTEM OF CLASSIFICATION ACCORDING TO BENTHAM AND HOOKER.

CLASS—DICOTYLEDONS.

Sub-class I Polypetalæ.—(Flowers usually with both sepals and petals and the latter distinct and not united.)

Series (1) *Thalamifloræ.*—Sepals and petals quite distinct, stamens hypogynous and ovary superior.

Series (2) *Discifloræ.*—Sepals distinct or united free or adnate to the ovary : stamens hypogynous ; a disc is present : ovary superior.

Series (3) *Calycifloræ.*—Sepals united, free or adnate to the ovary : stamens perigynous ; ovary superior or inferior.

Sub-class II Gamopetalæ.—(Flowers usually with both calyx and corolla and the latter always monopetalous.)

Series (1) *Inferæ.*—Ovary inferior and stamens equalling the petals in number.

Series (2) *Heteromeræ.*—Ovary superior ; stamens equal to petals, more or indefinite.

Series (3) *Bicarpellatæ.*—Ovary superior ; stamens equal or less than the corolla lobes ; carpels two.

Sub-class III Incompletæ.—(Monochlamydeæ.) (Flowers with a single whorl of perianth, i.e., the calyx.)

Series (1) *Curvembryeæ.*—Ovary with solitary ovules ; embryo curved in flowery endosperm.

Series (2) *Multiovulatæ.*—Ovary with indefinite ovules.

Series (3) *Micrembryeæ.*—Ovary with solitary ovules in the cells apo-or syncarpous ; embryo very small with endosperm.

Series (4) *Daphnales.*—Ovary of one carpel with one or more ovules ; perianth regular perfect and stamens perigynous.

Series (5) *Achlamydosporeæ.*—Ovary unilocular, 1 to 3 ovuled but ovules not clear until after fertilization.

Series (6) *Unisexuals.*—Flowers unisexual ; ovary one carpel or syncarpous ; ovules solitary or two in each cell ; sepals reduced or absent.

CLASS—MONOCOTYLEDONS.

Series (1) *Microspermæ.*—Inner perianth petaloid ; ovary inferior with three parietal placentas seeds very minute.

Series (2) *Epigynæ.*—Perianth partly petaloid ; ovary inferior and endosperm plenty.

Series (3) *Coronarieæ.*—Inner perianth petaloid, ovary free, superior endosperm present.

Series (4) *Calycinæ.*—Perianth sepaloid ; ovary superior.

Series (5) *Nudifloræ.*—No perianth ; ovary superior.

Series (6) *Apocarpæ.*—Perianth one or two whorls or absent ; ovary superior apocarpous.

Series (7) *Glumaceæ.*—Flowers single, axillary in the axils of bracts ; no perianth ; ovary one-celled and one-ovuled.

NATURAL ORDERS * GROUPED ACCORDING TO BENTHAM AND HOOKER'S SYSTEM.

DICOTYLEDONS.

POLYPETALÆ—

(1) *Thalamifloræ*—

Anonaceæ.
Nymphæaceæ.
Cruciferæ.
Capparideæ.

POLYPETALÆ—*cont.*

(1) *Thalamifloræ*—cont.

Malvaceæ.
Sterculiaceæ.
Tiliaceæ.

* Only those described in the next chapter are included here.

POLYPETALÆ—*cont.*
- (2) *Disciflorœ*—
  - Rutaceæ.
  - Meliaceæ.
  - Rhamneæ.
  - Ampelideæ.
  - Sapindaceæ.
  - Anacardiaceæ.
- (3) *Calyciflorœ*—
  - Leguminosæ.
  - Combretaceæ.
  - Myrtaceæ.
  - Cucurbitaceæ.
  - Ficoideæ.

GAMOPETALÆ—
- (1) *Inferœ*—
  - Rubiaceæ.
  - Compositæ.

GAMOPETALÆ—*cont.*
- (2) *Heteromerœ.*
  - Sapotaceæ.
- (3) *Bicarpellatœ*—
  - Apocynaceæ.
  - Asclepiadeæ.
  - Boragineæ.
  - Convolvulaceæ.
  - Solanaceæ.
  - Acanthaceæ.
  - Labiatæ.

INCOMPLETÆ—
- (1) *Curvembryœ*—
  - Amarantaceæ.
- (2) *Unisexuals*—
  - Euphorbiaceæ.
  - Urticaceæ.

MONOCOTYLEDONS.

Series (1) *Microspermœ*—Orchidæ.
Series (2) *Epigynœ*—Scitamineæ, Amaryllideæ.
Series (3) *Coronariœ*—Liliaceæ, Commelinaceæ.
Series (4) *Calycinœ*—Palmæ.
Series (5) *Nudiflorœ*—Aroideæ.
Series (6) *Glumaceœ*—Cyperaceæ, Gramineæ.

CHAPTER XVIII.

DESCRIPTION OF NATURAL ORDERS.

ANONACEÆ.

FOR this family the *Custard-apple* (*Anona squamosa*, L.) may be taken as a type. This is a small tree branching freely with leaves arranged bifariously on the twigs. Leaves are simple, alternate, exstipulate, shortly petioled, oblong, entire, dark green above and slightly glaucous beneath.

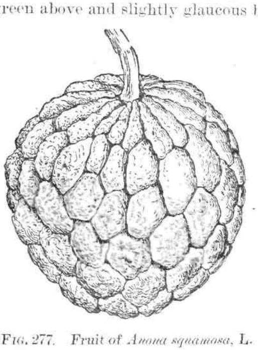


FIG. 277. Fruit of *Anona squamosa*, L.

Flowers arise singly from the leaf axils and the flower consists of three small triangular membranous sepals, valvate in bud, three petals, indefinite stamens and a superior ovary of many carpels. The petals are valvate in bud, fleshy, thick and somewhat triangular in section, narrow oblong and concave below. Stamens are spirally and closely packed on the prominent conical receptacle and hypogynous ; filaments are very short ; anthers long, two-lobed, and crested with the dilated end of the connective. Ovary consists of many carpels closely packed.

Fruit is a berry consisting of several fleshy carpels all fused together in one mass. Seeds are black, polished and oblong and possess endosperm which is in the form of folds (ruminate endosperm).

Anona reticulata, L., or the Bullock's-heart is another common tree under cultivation. This differs from the Custard-apple only in certain respects. Flowers are clustered in groups, instead of solitary, and the areolation on the surface of the fruit is not quite so distinct as in *A. squamosa*, L.

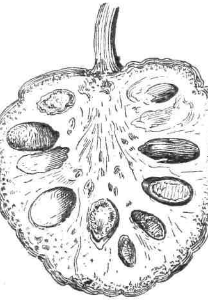


FIG. 278. Fruit of *Anona squamosa*, L., longitudinal section.

Polyalthia longifolia, Benth., is another common avenue tree of this order. Leaves are lanceolate with undulate margins, shining and studded with pellucid glands. Flowers arise from old branches in umbels, or short racemes. Petals are six, in two whorls of three thin. Fruit consists of free carpels.

Characters of the Order.— Plants belonging to this order are trees or scandent shrubs. Leaves are simple, alternate, exstipulate, short stalked, entire and generally bifarious.

Flowers are solitary, fascicled, umbelled or racemed. Sepals are three, valvate in bud and small. Petals are either six (in two series of three) or three. Stamens are numerous; hypogynous, closely and spirally packed on the receptacle; filaments are short, anther linear and usually crested by the

dilated end of the prolonged connective. Ovary is superior, consisting of closely packed carpels which are usually free (fused in Anona). Fruit is fleshy, of free carpels except in Anona. Seeds have *ruminate endosperm.*

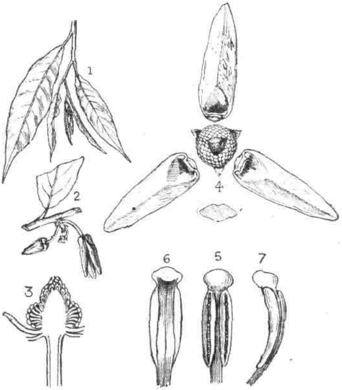


FIG. 279. Floral parts of *Anona reticulata*, L. 1, branch with young leaves ; 2, flowers ; 3, stamens and the pistil ; 4, parts of the flower ; 5, 6, 7, front, back and profile views of stamens.

This order is completely tropical. Other genera commonly found in South India, are Uvaria, Saccopetalum and Miliusa.

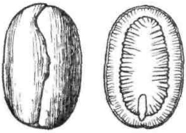


FIG. 280. Seed of *Polyalthia longifolia*, Benth. 1, entire seed ; 2, section of seed showing the embryo and ruminated endosperm.

NYMPHÆACEÆ.

The Water-lily and Lotus are the representatives of this family. Both are aquatics and are met with in tanks and ponds all over South India.

Nymphæa Lotus, L., or the Water-lily has a short underground stem and large leaves on very long stalks. The leaf blade is somewhat round in outline with a deep sinus at the base, attached to the stalk peltately, and floats on the surface of the water with the part where the petiole joins it being slightly raised and higher than the other parts. The lower surface of the blade is reddish and the spongy veins are very prominent and the upper surface is green, smooth and cannot be wetted with water.

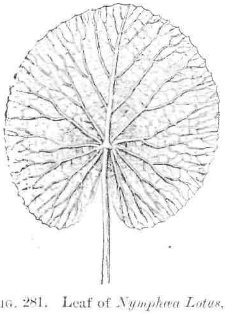


FIG. 281. Leaf of *Nymphæa Lotus*, L.

Flowers are solitary on long scapes, floating. Sepals are four, oblong. Petals are unequal, twelve or more, oblong, white or deep red. Stamens are about 35 to 40 or more; filaments are flattened at the base, the outer more so than the inner; anthers are without appendages. Ovary consists of many carpels fused with the fleshy receptacle.

Fruit is a soft spongy berry with 12 to 15 or more cavities lined with seeds. Seeds are somewhat globular, covered with tubercles appearing as lines and are enclosed by a sac-like aril.

The Lotus or *Nelumbium speciosum*, Willd., is another well-known plant of this family growing in temple tanks. It has

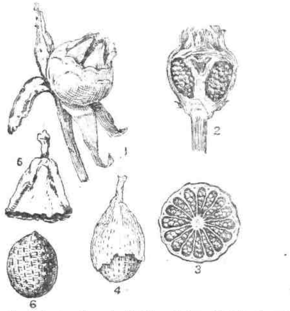


FIG. 282. *Nymphæa Lotus*, L. 1, fruit : 2, longitudinal and 3, transverse sections : 4, arillate seed : 5, 6 aril and seed separated.

FIG. 282-A. *Nelumbium speciosum*, Willd.

a creeping and branching stem with roots at the nodes. Leaves are very long stalked and the blade is round, raised above water and cup-shaped in the middle. Flowers are solitary, large, on long peduncles. Sepals are four or five. Petals are 15 to 20 or more, white or pink, unequal and deciduous. Stamens are many with club-shaped appendages to the anthers. Carpels ten to twenty separately sunk in the top-shaped receptacle.

Fruit consists of the top-shaped receptacle in which the ripe carpels are imbedded.

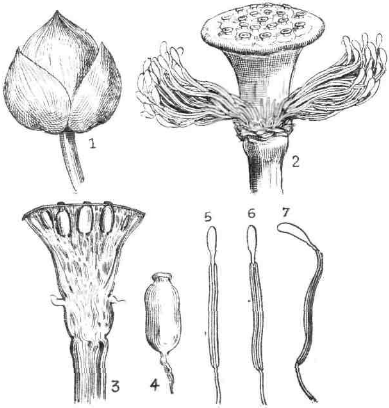


FIG. 283. *Nelumbium speciosum*, Willd. 1, flower bud ; 2, essential parts, stamens and pistil ; 3, the gynæceum cut through ; 4, carpel ; 5, 6, 7, stamens.

Characters of the Order.—Plants of this order are all aquatics with large leaves and flowers borne on long stalks, which are usually spongy on account of large air spaces. The sepals are usually four or five, free. Petals are many, unequal, free ; stamens are indefinite with flattened filaments.

The ovary consists of many carpels that are either fused with the receptacle or free and immersed in the receptacle. Fruit is a berry. Seeds are arillate or not.

CRUCIFERÆ.

The Mustard plant, *Brassica juncea*, L., serves as a good example of this family. It is an annual with sessile pinnately lobed leaves and long terminal racemes of yellow flowers. The racemes are at first corymbose and the axis elongates later, when fruits are formed.

FIG. 284. *Brassica juncea*, L. 1, raceme ; 2, stamens and pistil ; 3, petal ; 4, fruit (silique) ; 5, flower.

Flowers are without bracts. There are four narrow green sepals in two whorls, and the two lateral sepals of the inner whorl are slightly bulging at the base on account of the two glands opposite to them on the receptacle. Petals are free like the sepals, clawed, bright yellow and are crosswise in

one whorl. Stamens are six, tetradynamous ; the two shorter stamens are opposite the lateral bulged sepals and there are *two glands one near each of these stamens.* The ovary is superior of two carpels with parietal placentation. At first though unilocular a false septum is formed later and hence the fruit is two-celled. Fruit opens by two valves separating from below and leaving the septum with seeds on. Seeds are black, small.

This order is very well represented in temperate regions, *and in the tropical regions very few species occur.* In South India Cardamine and Capsella are the only genera occurring in a wild state on higher elevations. Other plants of this order, such as the Radish, Turnip, Cauliflower, Cabbage, Nolkhol are all usually cultivated.

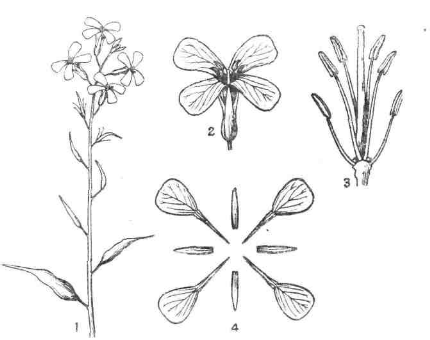


FIG. 285. Radish 1. inflorescence ; 2, flower ; 3, stamens and pistil ; 4, sepals and petals.

Characters of the Order.—All members of this family are herbs. Plants belonging to this family are easily recognised by the tetradynamous stamens, the cruciform clawed petals and the peculiar fruit with the false septum (silique).

CAPPARIDEÆ.

The Velai (*Gynandropsis pentaphylla*, DC.) plant of this family is an annual herb growing in waste places and it emits a peculiar strong smell.

The plant is erect, and branches well. Leaves are alternate, exstipulate, long stalked, palmately compound; leaflets five, sessile ovate-elliptic, acute, entire and hairy on both sides. Inflorescence is a terminal receme, at first corymbose and afterwards lengthening into a regular elongated raceme.

Flowers have bracts consisting of three sessile leaflets and long viscidly hairy stalks. Sepals are four, free, lanceolate. Petals are also four, white and clawed. There are six stamens that are attached to the gynophore, which carries on its summit the ovary. Fruit is unilocular, with parietal placentation and dehiscent.

This family is well represented in South India and the most common genera occurring in a wild state are Cleome, Capparis and Cadaba. The genus Cleome differs from Gynandropsis in not having a gynophore, but resembles it in other respects. In Capparis we have indefinite stamens and they are not attached to the gynophore. The fruit is a berry and not a dry capsule as in Cleome.

Cleome Chelidonii, L.f., is a weed of clayey soils easily recognised by the rose-coloured flowers. *Cleome viscosa*, L., is another one found everywhere and it is a sticky plant, as its name indicates and bears yellow flowers.

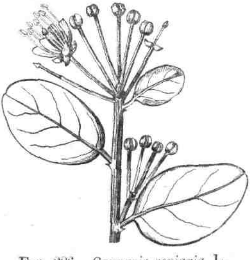


FIG. 286. *Capparis sepiaria*, L.

Capparis sepiaria, L., forms thick impenetrable bushes and flourishes everywhere in the scrubby jungles of South India. There are stipular thorns. The flowers are white, small and in umbels. The fruit alone is borne by the gynophore and it is a berry.

Cadaba indica, L., is another straggling shrub with simple oblong leaves and greenish flowers commonly found in this country. The flower has four stamens borne by the gynophore and the most striking feature of the flower is its tubular disc projecting from the centre of the flower. The fruit is torulose and the seeds are surrounded by a red aril.

FIG. 287. *Cadaba indica*, L.

Characters of the Order.—The plants of this family are herbs, shrubs or trees. Leaves are alternate, with or without stipular thorns, simple or compound. Flowers have four free sepals and petals with definite or indefinite stamens, attached to the gynophore or not. The ovary is one-celled, stalked or not. Fruit is capsular or berried, unilocular with parietal placentation.

MALVACEÆ.

The common garden Shoe-flower (*Hibiscus Rosa-sinensis*, L.) is a good representative of this family. It is a shrub, branching freely and bearing large showy axillary solitary flowers. Leaves simple, alternate with linear stipules; petiole is short and the blade is ovate with dentate margin.

Flowers are large, the peduncle is jointed and there are six or more linear bracteoles at the base of the calyx cup which has five triangular teeth. The corolla consists of five large, red, free petals adhering at the base to one another and to the staminal tube, contorted in æstivation. Stamens are monadelphous forming a tube, antheriferous only at the upper half and the anthers are kidney-shaped and one-celled. Ovary is superior, five-celled, with axile placentation; style is very long, slender, branching at the top into five stigmatiferous branches. The ovary does not develop into a fruit in the garden Hibiscus; but in many species of Hibiscus the fruit is a loculicidally dehiscing capsule.

The order is a large one and there are several species that have a wide distribution. The genera Sida, Abutilon, Urena and Pavonia are found everywhere. These genera differ

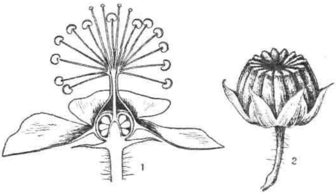


FIG. 288. *Abutilon graveolens*, W. & A. 1. flower cut vertically : 2. fruit.

from Hibiscus in several respects, though they are all alike in all essential characters. In all these genera, the fruit

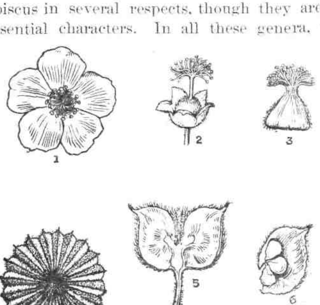


FIG. 289. Floral parts of *Abutilon indicum*, G. Don. 1, front view of flower; 2, pistil; 3, staminal tube; 4, top view of fruit; 5, vertical section of fruit; 6, a segment with seeds.

breaks into its component parts, i.e., it is a schizocarp; bracts are absent in Sida, Abutilon and there are five bracts in Urena, and Pavonia has five or more. The style branches

in Urena and Pavonia are twice as many as the carpels, but in Sida and Abutilon they are as many as the carpels.

Several species of Malvaceæ are under cultivation. The ordinary Cotton plant, *Gossypium herbaceum*, L., *Hibiscus cannabinus*, L., *H. esculentus*, L., and *H. sabdariffa*, L., are all cultivated in South India.

Thespesia populnea, Corr., is a common avenue and seashore tree. Other trees of this order which are of some economic importance are *Eriodendron anfractuosum*, DC., and *Bombax malabaricum*, DC.

The Characters of the Order.—Plants of this order are herbs, shrubs and trees. Leaves are alternate, stipulate, simple with palmate veins in some cases. Flowers are bisexual, axillary and solitary. Sepals are five, monosepalous. Petals are five, free contorted and adnate to each other at base and also to the staminal tube. Stamens are united into a tube, indefinite ; anthers are reniform, ultimately one-celled. Ovary is three to five or many-celled, with axile placentation. Fruit is either a capsule bursting loculicidally or a schizocarp, with dehiscent or indehiscent cocci. Seeds are reniform, naked or hairy.

STERCULIACEÆ.

This family is represented by eight or nine genera in South India and as types the two species *Melochia corchorifolia*, L., and *Waltheria indica*, L., occurring as weeds all over South India, may be examined.

Melochia corchorifolia, L., is an erect herb with stellately hairy branches. The leaves are simple, alternate, petiolate with small lanceolate stipules. The blade varies from oblong to ovate, serrate, glabrous above and stellately hairy below ; base of blade is five-nerved, rounded or cordate.

Flowers are regular, pentamerous in all their parts, densely crowded in axillary or terminal clusters, and with bracteoles. Sepals are free, though slightly connate at base, lanceolate. Petals are pink in colour and longer than the sepals. Stamens are five and united at base into a tube. Ovary is five-celled and two-ovuled.

Fruit is a loculicidally dehiscing capsule ; it is globose and enclosed by the persistent calyx. Seeds are black, somewhat angular and in each cavity there is only one seed.

Waltheria indica, L., is somewhat like *Melochia corchorifolia*, L., in habit and in the structure and arrangement of the flower. But the ovary is one-celled and two-ovuled and the fruit contains only one seed.

Helicteres Isora, L., is fairly abundant in all low jungles in South India and becomes very attractive when in flower, on account of the crimson flowers. The petals are irregular, the stamens are tubular and the ovary has a stalk. The fruit consists of five linear follicles more or less twisted spirally.

Several species of Pterospermum are found in the forests of low hills. The leaves of the trees of this genus vary very much and the fruits are loculicidal woody capsules, with winged seeds.

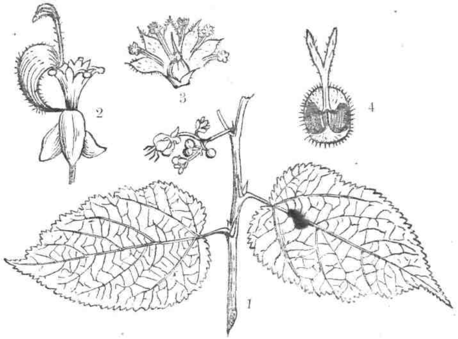


FIG. 290. *Guazuma tomentosa*, Kunth. 1, branch; 2, flower with one petal; 3, stamens and staminodes with pistil; 4, petal.

The tree *Guazuma tomentosa*, Kunth, is met with in many places as an avenue tree. The petals are concave with two strap-shaped narrow appendages at the apex and there are staminodes. The fruit is also striking in appearance, as it is woody and tubercled recalling to our mind the mulberry.

Characters of the Order.—The plants of this order are herbs, shrubs and trees. Leaves are alternate, stipulate, simple and shortly petioled. Inflorescence is cymose, axillary. Flowers are regular usually bisexual, though in some species unisexual. Sepals and petals are five and free. Stamens are definite in number, free, with or without staminodes and anthers two-celled. Ovary is five-celled with axile placentation. Fruit is usually a capsule.

The order is a tropical one.

TILIACEÆ.

This order is also a tropical order and five genera occur in South India. The species *Corchorus olitorius*, L., or any other species of Corchorus may be taken as a representative of this order.

Corchorus olitorius, L., is an erect plant sometimes growing to a height of four feet, with a tendency to branch freely. Leaves are alternate, very short stalked, with narrow stipules shorter than the petiole. The blade is ovate to ovate-lanceolate, serrate with the two lowest teeth prolonged downwards as a tail, at base rounded and three to five-nerved.

Flowers are in groups of two or three, axillary with short pedicels. Flower buds are distinctly angled, obovate and tipped with a cusp. There are five sepals and petals, both being free. Stamens are many, free, with two-lobed anthers. Ovary superior, usually five-celled.

Fruit is a cylindrical capsule with ten ribs, five-celled with transverse partitions between the seeds. Seeds are somewhat triangular, dull black.

Triumfetta rhomboidea, Jacq., is another common weed with a wide distribution. This is easily recognised by its small globose fruits, covered with hooks.

The species of Grewia are also very widely spread and they are conspicuous by their cymose inflorescence and drupaceous fruit.

Another genus with many species mostly confined to hills is Elæocarpus. This genus has large flowers with laciniate petals and long linear anthers opening by pores at the apex. The fruit is a one-seeded, one-celled drupe.

The tree *Berrya Ammonilla*, Roxb., which yields the valuable timber, Trincomali wood, is a member of this family.

FIG. 291. *Corchorus olitorius*, L. 1, a branch; 2, young flower-bud; 3, flower; 4, stamens; 5, pistil; 6, fruit; 7, transverse section of fruit; 8, capsule burst open; 9 and 10, seeds.

Characters of the Order.—This order includes trees, shrubs and rarely herbs. Leaves are alternate, simple, stipulate. Flowers are regular, bisexual. Sepals and petals are three to five. Stamens are usually indefinite inserted on the edge of the receptacle, and free; anthers two-celled. Ovary is seated on a distinct stalk (torus), two- to ten-celled. Fruit is one- to many-celled, dry or fleshy, dehiscent or indehiscent.

RUTACEÆ.

The common orange, *Citrus aurantium*, L., will serve as an example of this order.

This is a tree with numerous spinescent young branches. Leaves are alternate, exstipulate, compound and unifoliolate with winged petioles. The leaflet is elliptic or oblong elliptic, studded with pellucid oil glands, entire or crenate. Flowers are clustered as small cymes. The calyx is

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somewhat cup-shaped, usually five-toothed. Petals are usually five, white, linear, oblong, thick. Stamens vary in number from ten up to twenty or sometimes even more. Ovary is eight to many-celled. Ovules are many and biseriate and placentation axile; the style is cylindric, prominent with a capitate stigma. Fruit is a many-celled berry with a leathery rind and fleshy hairs within the cavities growing from the inside of the pericarp. Seeds have a coriaceous testa and they are often polyembryonic.

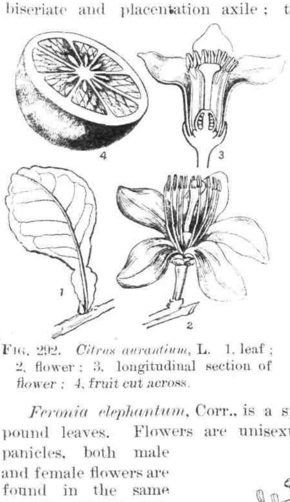

FIG. 292. *Citrus aurantium*, L. 1, leaf; 2, flower; 3, longitudinal section of flower; 4, fruit cut across.

Other species that may be examined are *Feronia elephantum*, Corr., *Ægle Marmelos*, Corr., *Murraya Kœnigii*, Spreng, *M. exotica*, and *Toddalia aculeata*, Pers.

Feronia elephantum, Corr., is a spinous tree with compound leaves. Flowers are unisexual, dull red and in panicles, both male and female flowers are found in the same panicle. The fruit is a berry with a woody rind. Seeds are immersed in pulp.

Toddalia aculeata, Pers., is a very prickly shrub and it forms an impenetrable thicket on the plains, but on the hills it grows larger.

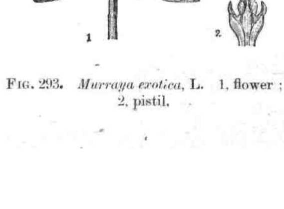

FIG. 293. *Murraya exotica*, L. 1, flower; 2, pistil.

Characters of the Order.—Many of the members of this family are tropical in distribution and consist of trees, shrubs and herbs and all parts abound in oil glands, though these are more prominently seen in leaves as translucent glands. Leaves are simple or compound, alternate and without stipules. Flowers are bisexual usually with four or five petals and a cupular calyx with the same number of teeth. Stamens vary in number from five to ten or more. There is a distinct disc inside the stamens. Ovary is four to many-celled, style stout and stigma capitate. Fruit is usually a berry.

MELIACEÆ.

This is another family whose members are widely distributed in the warm regions of the Old and the New World. The common Margosa or Nim tree is a good representative of this family.

Melia Azadirachta, L., is a large tree with a straight trunk. Leaves are found crowded towards the ends of the branches. They are alternate, exstipulate, compound, odd pinnate. Leaflets are obliquely lanceolate or falcate, toothed, sub-opposite and vary in number from nine to thirteen.

FIG. 294. *Melia Azadirachta*, L. 1, inflorescence; 2, flower; 3, longitudinal section of a flower; 4, staminal tube laid open; 5, pistil.

Flowers are regular, hermaphrodite and in narrow axillary panicles. Calyx is finely hairy and deeply five-lobed. Petals are five, narrowly obovate oblong or spathulate, ciliate. Stamens form a tube narrow at base and somewhat broad at the top with recurved teeth, anthers are ten and opposite the teeth. Ovary is three-celled, style is longer than the ovary and the stigma is three-toothed.

Fruit is a drupe. Seed without endosperm, ellipsoidal, single with very thick cotyledons.

Other members usually met with in the forests of South India are *Cipadessa fruticosa*, Bl., *Amoora Rohituka*, W. & A., *Walsura piscidia*, Roxb., and *Heynea trijuga*, Roxb. Some species of this order yield well known timbers. *Chickrassia tabularis*, A. Juss., yields the "Chittagong wood" or the white "Cedar." The well known "satin wood" is the timber of *Chloroxylon Swietenia*, DC. *Cedrela Toona*, Roxb., is another valuable timber tree known by the name Toon or the Indian Mahogany.

Amoora Rohituka, W. & A., has large capsular fruits with seeds each of which is immersed in a very conspicuous scarlet aril.

Characters of the Order.—The order includes shrubs and trees. Leaves are alternate, exstipulate and compound. Flowers are regular, hermaphrodite and in axillary or terminal panicles. Calyx is four- or five-lobed. Petals are four or five, usually free, imbricate or valvate. Stamens are five to ten; filaments united into a tube; anthers are introrse. Disc is present or absent. Ovary is two- to five-celled; style is simple with a capitate stigma. Fruit is a capsule, a berry or a drupe. Seeds are winged or not.

RHAMNEÆ.

The tree *Zizyphus Jujuba*, Lamk., is a good type of the family. It is a small tree widely distributed in this country.

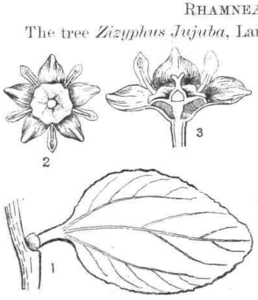

FIG. 295. *Zizyphus Jujuba*, Lamk. 1, leaf; 2, flower; 3, flower, cut vertically.

The tree is generally small but branching very much. Leaves are alternate with stipular thorns, shortly stalked and simple; the blade is ovate-elliptic, unequal at base, three-nerved, finely dentate, green above and densely hairy below.

Flowers are in axillary cymes, small and

greenish yellow. The calyx consists of five, free, triangular sepals, woolly outside, valvate in bud, keeled on the inner face and petals are five, concave, very small. Stamens are five, opposite the petals. Ovary is immersed in a ten-lobed distinct disc, two-celled ; style two-branched.

The fruit is globose and drupaceous, one- or two-seeded.

The other species of Zizyphus usually met with in South India are *Z. Œnoplia*, Mill., *Z. rugosa*, Lamk., and *Z. xylopyrus*, Willd.

Scutia indica, Brongn., a straggling shrub occurring as bushes in all scrub jungles is a member of this family. The branches are armed with recurved prickles.

Ventilago madraspatana, Gærtn., is another scandent shrub widely distributed ; it is easily recognised by the shining leaves with peculiar parallel close-set venation and by its winged fruits.

Characters of the Order.—The species of this family are trees or shrubs, erect or scandent. Leaves are alternate stipules small or spinescent. Flowers are regular, bisexual, small, greenish and in cymes. Calyx has four or five triangular, keeled sepals that are valvate in bud. Petals are four or five, inserted on the throat of the calyx tube, small, concave. Stamens are four or five opposite the petals and embraced by them, and are inserted outside the disc ; anthers versatile. Diso is fleshy, filling the calyx tube, entire or lobed. Ovary is three-celled, immersed in the disc ; style erect two- to four-fid.

Fruit is either a drupe or it is winged. Seeds have endosperm.

Most of the species are of the warm regions of the world

AMPELIDEÆ.

This family is represented in South India by the two genera Vitis and Leea.

Of the many species of Vitis commonly met with in this country, *Vitis quadrangularis*, Wall., may be examined as a type.

Vitis quadrangularis, Wall., is a well known quite common climber, conspicuous by its fleshy, square, slightly winged stems with deep constrictions and simple tendrils at

the nodes. The axis though straight is a sympode. Leaves are alternate with petioles and somewhat ovate conspicuous small stipules; the blade is ovate, sometimes lobed, cordate or rounded or cuneate at base. Flowers are in cymes that are open and loose and the inflorescences are usually opposite the leaf. Flowers are regular, small or whitish, bisexual and tetramerous. Calyx is small, four-toothed. Petals are four, hooded. Stamens are opposite the petals. Disc is distinct, four-lobed. Ovary is two-celled, with two ovules in each cell. The fruit is an ovoid berry, red when ripe.

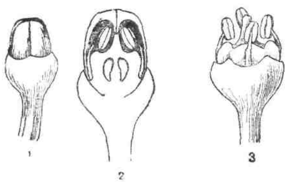

FIG. 296. *Vitis quadrangularis*, Wall. 1. flower-bud; 2. flower-bud, longitudinal section; 3. flower, without the petals.

The species of Leea can easily be recognised by their erect shrubby habit, compound leaves and large sheathing stipules.

Characters of the Order.—The members of the family are shrubs, mostly climbing by means of tendrils. Leaves are alternate, stipulate, simple or compound. Inflorescence is cymose. Flowers are regular and bisexual. Calyx is four- or five-lobed, cup-shaped. Petals are four or five, concave, valvate in bud, caducous. Stamens are four or five, free or united: but the filaments are opposite to the petals. Disc is large, annular. Ovary is two-celled in Vitis and six-celled in Leea. Fruit is a berry. Seeds have endosperm.

SAPINDACEÆ.

The common balloon-vine, *Cardiospermum Halicacabum*, L., is a member of this family. It is a tendril climber with very wiry stems. Leaves are alternate, exstipulate, twice compound, with long petioles; leaflets are lanceolate, coarsely toothed, slightly hairy or glabrous and have acute tips.

Flowers are small, irregular, polygamous and are arranged in umbellate cymes; the flower stalks are slender but the

peduncle is stiff and erect, with two tendrils just below the flowers. The calyx consists of four free sepals, the two *outer being smaller and the two inner larger and thin. There are four petals, two large with scales and two small and lower* with small crested scales : just *opposite the small petals* there are two glands representing the disc. Stamens are eight, eccentric with hairy unequal filaments. The ovary is globose, three-celled with a single ovule in each.

Fruit is a three-valved inflated capsule : it is pyriform and compressed from top, and slightly winged at the corners. Seeds are black with a white heart-shaped mark or aril (hence the generic name Cardiospermum).

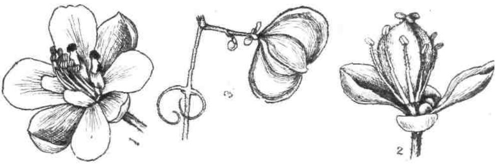

FIG 297. *Cardiospermum Halicacabum*, L. 1. male flower ; 2. bisexual flower ; 3. fruit. Note the scales in 1 and the glands in 2.

Another common species *Cardiospermum canescens*, Wall., may also be examined. It differs from *C. Halicacabum*, L., by having larger flowers, larger rounded capsules.

Allophylus Cobbe, Bl., is a shrub very commonly met with in low forests and even in scrubby jungles. It is easily recognised by the three foliolate leaves crowding at the extremities of branches, and the axillary racemes of small flowers, replaced later by small red berries.

Sapindus emarginatus, Vahl., is the Soapnut tree. It is a large tree with compound leaves having four to six oblong emarginate leaflets and with large panicles of flowers. The fruit consists of three distinct fleshy lobes, each separating with a single large black seed.

Dodonæa viscosa, L., is a low shrub with diœcious or polygamous flowers found in dry places, all over the plains.

It grows almost into a tree on high hills. The plant is easily recognised by the crowded, lanceolate, shining leaves and the winged capsules.

Characters of the Order.—Except the species of Cardiospermum, all the other members of this order are either shrubs, or trees. The leaves are mostly exstipulate, and usually compound. The flowers are generally small, regular or irregular, polygamous or diœcious. There are four or five sepals that are valvate or imbricate in bud. We have the same number of distinct petals, that are unequal and sometimes with scales as outgrowths. There is a disc which varies in its character. Of stamens there are usually eight, but in some species it may vary from five to ten. The insertion of stamens may be inside the disc or unilateral. The ovary is two-or three-celled, one-or two-ovuled. The fruit is indehiscent and fleshy or capsular. Seeds are arillate or not, but without endosperm.

The members of this family abound in the tropics and are most abundant in America.

ANACARDIACEÆ.

The mango tree, *Mangifera indica*, L., may be examined as a type of this family. It is a tree with a tendency to grow tall and large, containing an acrid juice in its branches and fruit. Leaves are glabrous and shining, and are crowded together at the ends of branches. There are found at the extremities of branches terminal scaly buds from which emerge young leaves, which are reddish in colour but becoming green later. Leaves are simple, exstipulate, alternate and the petioles are short; the blade varies in shape from oblong to oblong lanceolate or lanceolate; the margin is entire, but sometimes wavy.

Flowers are small polygamous and in terminal panicles. Sepals are five, somewhat shorter than the petals, concave and ovate. There are five oblong petals with three ridges on the inner face and the margins reflexed. Disc is prominent fleshy and five-lobed. There is a single perfect stamen inserted within the disc, the others being small and imperfect; the anther is purple. Ovary is one-celled and one-seeded with a lateral style.

Fruit is a drupe, varying in size according to the varieties. Seed, single, large with massive cotyledons.

FIG. 298. *Mangifera indica*, L. 1, flower : 2, vertical section of flower.

The family is not a very large one and in India the following species are fairly common.

The two trees *Buchanania angustifolia*, Roxb., and *B. latifolia*, Roxb., are fairly common in the forests and scrubby jungles. They are easily recognised by their having their panicles shorter than the leaves. Further, the flowers are hermaphrodite and possess eight stamens. The drupes are small.

The deciduous tree *Odina Wodier*, Roxb., is a well known one. It can be recognised with ease by its smooth bark and by the branches bearing unisexual flowers in spikes, at a time when they are bare of leaves. Leaves are pinnately compound.

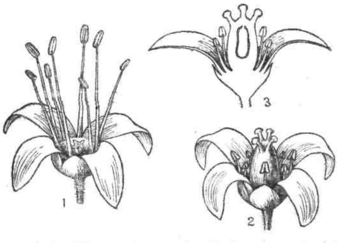

FIG. 299. *Odina Wodier*, Roxb. 1, male flower ; 2, female flower ; 3, female flower, longitudinal section.

The Cashew-nut tree (*Anacardium occidentale*, L.) is widely spread. This tree has a very crooked trunk and the

branches are low lying in sandy tracts. Leaves are large rounded at the apex. Flowers are in terminal panicles and the pedicels of flowers grow and become fleshy and massive bearing the fruit at its end.

Characters of the Order.—Most of the members of this family are trees with acrid juice. Leaves are alternate and exstipulate. Flowers are small, regular, polygamous, unisexual or bisexual and are in panicles. Sepals and petals are free and four to five in number. Stamens are same in number as the petals, or twice and are inserted inside a conspicuous disc. Ovary is superior, one-celled and one-ovuled. Fruit is a drupe. Seeds are large and without endosperm.

LEGUMINOSÆ.

This family being a large one it is necessary to select as types three or four plants.

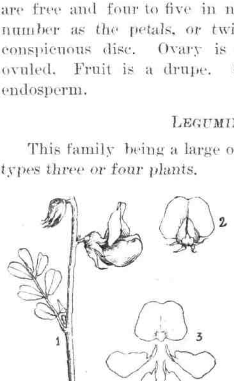

FIG 300. *Tephrosia villosa*, Pers. 1, floral branch ; 2, flower : 3, petals ; 4, stamens and the pistil ; 5, fruit and seed.

The plant *Crotalaria verrucosa*, L., is a copiously branching shrub with quadrangular stems. Leaves are alternate, simple with well developed, green, semilunar stipules ; the blade is large broadly ovate, with entire but wavy margins and prominent veins. Flowers are large and are in racemes that are leaf-opposed. The bract is narrow, acuminate and shorter than the pedicel. The calyx is finely hairy outside with five triangular, acuminate teeth. The corolla is papilionaceous, and blue in colour ; standard is somewhat orbicular in shape ; the wings are shorter than the standard and the keel-petals which are equal to the wings in length are

completely united and are prolonged into a sharp curved beak. The stamens are ten, monadelphous with dimorphous anthers. Ovary is monocarpellary, one-celled and many-ovuled ; style is long with a minute stigma.

Fruit is a turgid, straight, sessile legume with ten or twelve seeds.

Other species of Crotalaria that are of common occurrence are *C. retusa*, L., *C. biflora*, L., *C. juncea*, L., and *C. medicaginea*, Lamk.

Tephrosia purpurea, Pers., and *T. villosa*, Pers., are found everywhere in South India. The flowers are in racemes and the corolla is papilionaceous and pink in colour. Stamens are diadelphous and the legume is flat and curved.

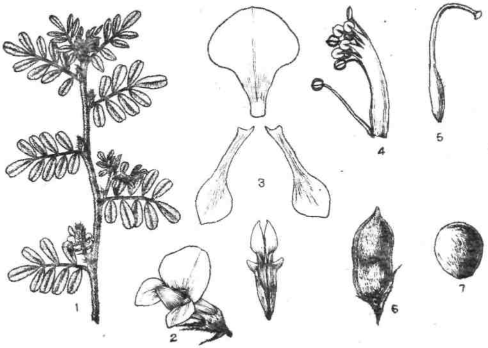

FIG. 301 *Indigofera enneaphylla*, L. 1, branch ; 2, flower ; 3, petals ; 4, stamens ; 5, pistil ; 6, fruit ; 7, seed.

Several species of Indigofera besides the cultivated indigo plant are met with. *Indigofera enneaphylla*, L., is a prostrate herb found in all waste places and amidst pastures. It has small compound leaves and small bright, deep pink flowers. *I. trita*, L., is an erect plant frequently met with in all situations.

The genus Indigofera is easily recognised by the hairs th are fixed by the centre, the keel-petals spurred on bo sides, and the diadelphous stamens.

The species of Leguminosæ that have a papilionaceo corolla form a distinct sul order Papilionaceæ. There a many genera and species c this sub-order growing i South India in a wild stat The following are a few o them: *Sesbania grandiflora* Pers., *Abrus precatorius*, L. *Teramnus labialis*, Spreng. *Clitoria Ternatea*, L., *Rhynchosia minima*, DC., *Desmodium triflorum*, DC., *D. biarticulatum*, Benth., *Pongamia glabra*, Vent., *Zornia diphylla*, Pers., and *Alysicarpus monilifer*, DC. Besides these many species such as, *Dolichos Lablab*, L., *Canavalia ensiformis*, DC., *Phaseolus Mungo*, L., *Vigna Catiang*, Endl., *Cicer arietinum*, L., *Cajanus indicus*, Spreng., and several others are under cultivation.

FIG. 302. *Desmodium triflorum*, DC.

Cassia auriculata, L., or *Cassia siamea*, Lam., may be examined as a type of the next sub-order Cæsalpineæ. The former is a shrub and the latter a tree. The leaves are compound in both and the leaflets are oblong. The stipules are large and semi-lunar in *C. auriculata* and they are small and caducous in *C. siamea*. Flowers are in racemes, and corymbose, but simple in the first and compound in the second. The calyx consists of five, free, petaloid sepals unequal, concave and quincuncially imbricate. There are

five yellow petals with long claws, and they are imbricate in bud with the upper petal innermost. Stamens are ten, some

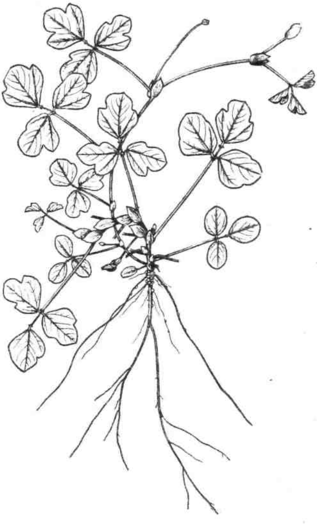

FIG. 303. *Phaseolus trilobus*, Ait.

only perfect, and three being barren; anthers open by apical pores. The ovary is monocarpellary and one-celled with many ovules.

Fruit is a thin flat legume dehiscing by both sutures. Seeds without endosperm.

Cassia Fistula, L., is a tree very conspicuous in the hot weather on account of the abundant drooping racemes of bright yellow flowers and long black cylindrical fruits.

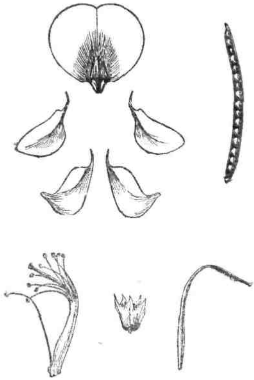

FIG. 304. *Vigna Catiang*, Endl.

The garden plant *Cæsalpinia pulcherrima*, L. (the Peacock flower) belongs to this sub-order. It is a low, very

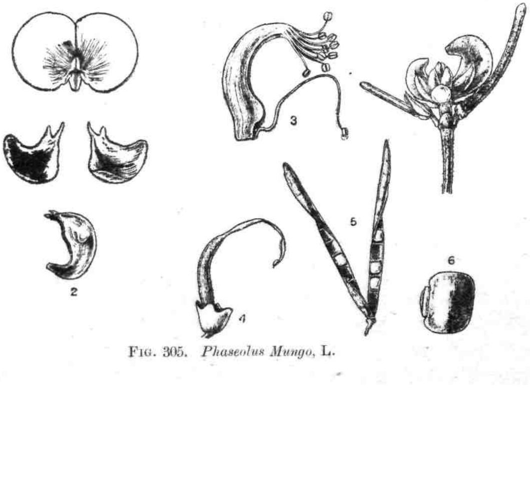

FIG. 305. *Phaseolus Mungo*, L.

much branching tree with large terminal racemes of yellow or red flowers. The petals and sepals are very much as in Cassia, but the claws of the petals are more marked and all the ten stamens are fertile. The filaments are fine and very long, sometimes hairy at the base.

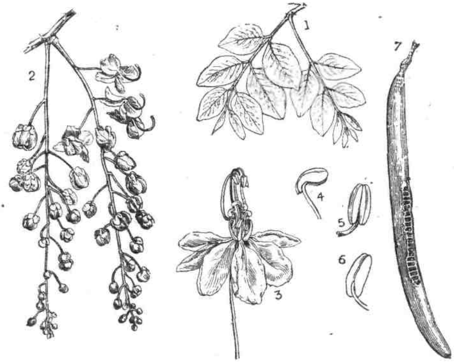

FIG. 306. *Cassia Fistula*, L.
1, leaves; 2, inflorescence; 3, flower; 4, 5, 6, stamens; 7, fruit.

The tamarind tree, *Tamarindus indica*, L., is another example of this order. It is a large tree with compound leaves whose leaflets are sensitive to a certain extent to light. The flowers are in racemes, and they have both bracts and bracteoles. The calyx is somewhat elongated at the base in the form of a tube and has four segments only. There are only three petals with red veins, and three stamens. The fruit is a legume with a fleshy mesocarp.

The genus Bauhinia is easily recognised by the two-lobed or cleft leaves and by the spathaceous calyx.

As examples for the sub-order Mimoseæ the Babul, *Acacia arabica*, Willd., or any other species of Acacia may be examined.

The Babul or *Acacia arabica*, Willd., is a small tree with numerous branches bearing stipular spines. Leaves are alternate, stipulate, with glands on the rachis, bipinnate;

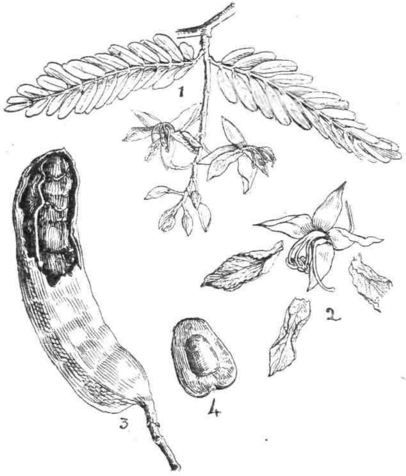

FIG. 307. *Tamarindus indica*, L.
1, branch; 2, floral parts; 3, fruit; 4, seed.

leaflets are small. (See fig. 151-B.) Flowers are grouped in heads that are fascicled in the axils of leaves. There are two bracteoles. The calyx is bell-shaped with five very short teeth. Corolla is tubular, yellow with triangular lobes. Stamens are indefinite, very much exserted. Ovary is one-celled with many ovules.

Fruit is a stalked, compressed legume covered with soft white hairs and indented on both sides between the seeds and hence moniliform.

Acacia leucophlœa, Willd., differs from the Babul in having white flowers and pods not constricted. The yellow flower heads of *A. Farnesiana*, Willd., are very fragrant, but the turgid cylindrical legumes have an offensive smell. *Acacia concinna*, DC., is a huge climber whose fruits are largely used as soap. The very much branched shrub *Dichrostachys cinerea*, W. & A., with its very pretty spikes of red and yellow flowers forms a special feature in some scrubby jungles. Another tall tree, quite conspicuous by its flat broad and thin fruits and white globose flower heads, is *Albizzia Lebbek*. The plant largely used for hedges, *Pithecolobium dulce*, Benth., possesses legumes circinately twisted and seeds with massive arils.

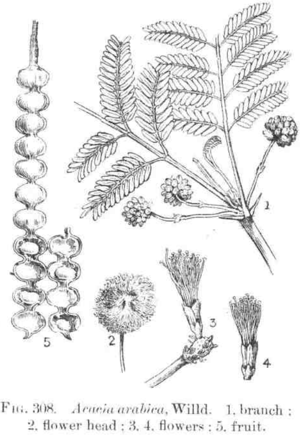

FIG. 308. *Acacia arabica*, Willd. 1, branch; 2, flower head; 3, 4, flowers; 5, fruit.

Characters of the Order.—The members of this order are extremely varied in their habit. They are herbs, shrubs, climbers and trees. Leaves are simple or compound, alternate, usually stipulate. Flowers, regular or irregular and bisexual. Sepals

FIG. 309. *Pithecolobium dulce*, Benth. 1, branch; 2, 3, flower-head; 4, flower.

are five, free or united. Petals are five, free. Stamens are ten or indefinite, free or united in various ways. Ovary is monocarpellary, one-celled and many ovuled. Fruit is a legume.

S. order (1)—*Papilionaceæ*.—Flowers, papilionaceous, the standard being the outermost in the flower bud. The stamens are either monadelphous or diadelphous.

S. order (2)—*Cæsalpineæ*.—Flowers are regular but the petals are usually clawed and the uppermost one is the innermost in the flower bud. Stamens are ten, all or only a few fertile and are much exserted: filaments are always free.

S. order (3)—*Mimoseæ*.—Flowers are usually small, collected together in heads or spikes, bisexual, but also with male and barren flowers in the same head or spike in some genera. Sepals and petals are valvate in bud. Stamens are definite or indefinite, exserted and free.

The most marked feature of this order is undoubtedly the fruit, which is a legume in most cases. But there is a large amount of variation in the structure of the fruit. We have dehiscent, as well as indehiscent dry fruits; the pericarp is also pulpy in some cases and in others the fruit becomes very turgid and cylindrical: there are also winged fruits that are really samaras. In spite of all these variations, they are all monocarpellary.

This family besides being the second largest order containing over 6,000 species, comprises more useful plants than any other order, except probably Gramineæ.

COMBRETACEÆ.

The tree *Terminalia Arjuna*, W. & A., is a good example of this family. This is a large tree with smooth greenish white bark, peeling off in large pieces. Leaves are alternate and subopposite simple and exstipulate, oblong to elliptic oblong, with short petioles. There are also two glands at the base of the leaf close to the petiole, one on each side.

Flowers are in spikes, with short bracteoles. The calyx is campanulate with five triangular teeth. Petals are absent. Stamens are ten and inserted on the disk clothed with hairs. Ovary inferior, one-celled with two or three pendulous ovules.

Fruit is a fibrous-woody drupe with five hard projecting wings. Seed single and without endosperm.

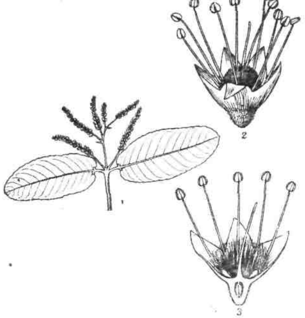

FIG. 310. *Terminalia Arjuna*. W. & A. 1. flower bearing branch ; 2. flower ; 3. longitudinal section of flower.

Instead of this species, *Terminalia Catappa*, L., and *T. Chebula*, Retz., may be examined. *Calycopteris floribunda*, Lamk., is a scandent shrub found everywhere on the West Coast and it is easily recognised by its small ellipsoidal fruits crowned by the persistent calyx. When the stem is cut during hot weather large quantities of water flow from the cut ends.

Gyrocarpus Jacquini, Roxb. (*G. americanus*, Jacq.) is a deciduous tree and is very conspicuous during the hot weather on account of the fruits with two large wings (see fig. 252) (Calyx segments).

Characters of the Order.—This order is a very well defined one with only a few species. They are either trees, or scandent or erect shrubs. Leaves are alternate or opposite, simple, exstipulate and the petioles often bearing glands at the top. Flowers are in spikes and are small without petals. Calyx four to five fid. Stamens are free, equal or double the calyx lobes. Ovary is inferior, one-celled with two or more pendulous ovules. Fruit is usually dry and indehiscent, in some drupaceous and winged. Seed single, without endosperm, cotyledons convolute.

MYRTACEÆ.

The evergreen tree *Eugenia Jambolana*, Lamk., is a suitable type for this order. It is a large tree with coriaceous

shining leaves that are opposite, exstipulate, gland dotted and petioled. The leaf blade is elliptic or oblong with an intra-marginal vein. Flowers are small in panicled cymes, usually fragrant and white. The calyx is short with four lobes. Petals are four, falling away in one piece, though free. Stamens are indefinite and the filaments are all folded inwards in the bud : anthers are versatile. The ovary is inferior, two-celled, with many ovules in each cell. Fruit is a dark purple ellipsoidal or globose berry, with a single seed.

The Guava tree (*Psidium Guyava*, L.) may be selected as a type if species of Eugenia are not available. The leaves of this plant are opposite, oblong with very prominent veins. Flowers are large, solitary or in simple cymes. Fruit is an inferior berry with persistent calyx lobes at the top.

FIG. 311. *Psidium Guyava*, L.

Many species of Eugenia are met with in the forests of South India. One of the commonest trees found scattered, here and there in the forests both on the East Coast and West Coast is *Careya arborea*, Roxb. It is a very striking one on account of its large obovate leaves collected at the ends of branches, large flowers and big green berries.

Characters of the Order.—The members of this family are mostly trees though there are one or two shrubby species.

The leaves are opposite, simple, exstipulate, entire, gland-dotted with an intra-marginal nerve. Flowers are regular, bisexual, solitary, in cymes, or cymose panicles. The calyx is superior, with four or five teeth. Petals are four or five, free, inserted at the margin of the disk, falling away in one piece. Stamens are numerous, filaments long and conspicuously coloured and folded down in the bud. Ovary is superior, one-celled with one or many ovules.

Fruit is a berry with the calyx limb on its top, one-celled, one-seeded or with many seeds imbedded in pulp.

CUCURBITACEÆ.

The pretty common creeper of the hedges, *Cephalandra indica*, Naud., is a good example of this order. The plant climbs by means of simple tendrils and the stem is thin and grooved. The leaves are alternate, exstipulate, simple and petiolate ; the blade is palmately five-lobed and the depth of lobing varies very much from being very deep to mere angles, and there are five veins at the cordate base, sometimes with glands between the nerves. Flowers are diœcious. Both male and female flowers are axillary and solitary. The calyx is narrow, bell-shaped and has five long teeth, and the corolla is campanulate, white and five-lobed. The corolla and the calyx are similar in both the kinds of flowers. Stamens are three with the filaments forming a column. The anthers of two stamens are complete but that of one is half and they are all united. The anther lobes are long and sinuously folded. The ovary is inferior, narrowly fusiform, glabrous, one-celled with three parietal placentas, ovules many. There are three bifid stigmas.

The fruit is a berry, ellipsoidal or oblong with white stripes or not, beautiful scarlet in colour when fully ripe. Seeds are obovoid.

Any of the cultivated species of the genus Cucurbita may also be examined. These are all large climbers with hairy stems and large leaves, and the tendrils are usually three or four-fid. Flowers are very large, yellow and monœcious. The calyx, corolla and the stamens are all like those of Cephalandra, but are larger. Fruit is a large berry with parietal placentas (Pepo).

Many of the members of this family are cultivated. All the Gourds, Cucumbers and Melons belong to this family. The plants, *Cucumis pubescens*, Willd., and *C. trigonus*, Roxb., occur in a wild state and they differ from Cephalandra and Cucurbita in having their connectives produced beyond the anther lobes forming a kind of crest. *Trichosanthes anguina*, L., or the Snake gourd has fimbriate petals and the Bitter gourd, *Momordica Charantia*, L., is easily recognised by its

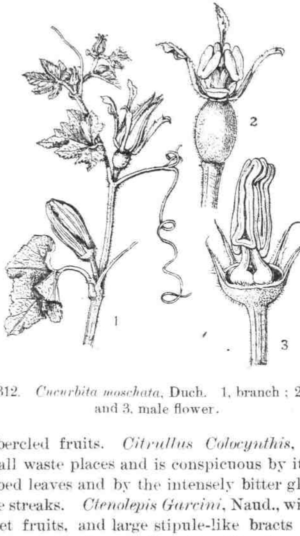

FIG. 312. *Cucurbita moschata*, Duch. 1, branch ; 2, female and 3, male flower.

fleshy tubercled fruits. *Citrullus Colocynthis*, Schrad., is found in all waste places and is conspicuous by its palmately deeply lobed leaves and by the intensely bitter globose fruits with white streaks. *Ctenolepis Garcini*, Naud., with its pretty tiny scarlet fruits, and large stipule-like bracts and *Mukia scabrella*, Arn., with its round bright red berries are occasionally met with, all over South India.

Characters of the Order.—This is a very well defined order, consisting mostly of climbers with hollow stems and simple or branched tendrils. Leaves are simple, alternate,

exstipulate, cordate at base, entire or palmately lobed and with coarse hairs. Flowers yellow or white, monœcious or diœcious, solitary or racemed. The calyx tube is adnate to the ovary and so the calyx lobes are superior. The sepals and petals are five in number. Petals are united, rarely free.

FIG. 313. *Trichosanthes anguina*, L. The left hand figure is a branch with female flowers and the right hand one is an inflorescence of male flowers.

Stamens are three attached to the calyx tube; anthers free or cohering, lobes conduplicate or flexuose, and the connective produced beyond the apex of the anther or not. Ovary is inferior, three carpellary, but one or three celled with three parietal placentas. Fruit is a berry with a hard rind. Seeds many and usually flat.

FICOIDEÆ.

This is a small order represented by a few genera. The most troublesome weeds *Trianthema monogyna*, L., and *T. decandra*, L., are plants of this order. Both are herbs with prostrate branches springing from a stout root. The leaves are petiolate, opposite, unequal and entire; in the former it

is round or obovate with petioles somewhat dilated and membranous at the base and that of the smaller leaf forms a pouch in which the flowers are situated : in the latter the leaves are elliptic-oblong and the petioles are dilated and amplexicaul at base, but do not form pouches enclosing flowers and fruits.

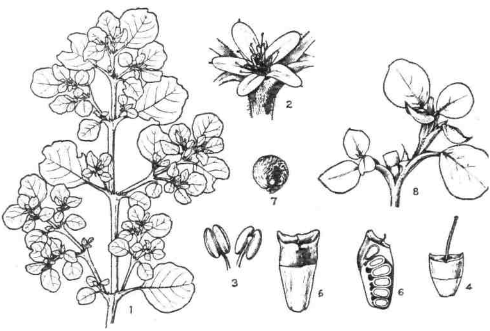

FIG. 314. *Trianthema monogyna*, L. 1. branch : 2. flower : 3. stamens ; 4. pistil : 5. fruit : 6. vertical section of fruit : 7. seed : 8. leaf pouch opened to show the position of fruit.

Flowers are solitary, sessile and within the petiolar pouch in *T. monogyna*, but they are in axillary dichasiums in *T. decandra*. Calyx consists of five deep lobes bearing a short process at the apex and coloured light pink within. Petals are not present. There are ten to twenty stamens in *T. monogyna*, and ten stamens only in *T. decandra*. Ovary is free, superior, sessile and truncate.. Style is single in *T. monogyna* and two in *T. decandra*. Fruit is a capsule, membranous below, and hardened into a cap above, which gets detached by circumcissile dehiscence. Seeds are three to five, black, reniform or orbicular, striate or muricated.

Trianthema crystallina, Vahl., is also fairly common in open waste places. It is a small much branched herb, with prostrate branches and woody root-stock.

Many species of Mollugo are also met with as weeds everywhere. *Mollugo hirta*, Thunb., is extremely common in clayey soil and tank beds, and this plant can easily be recognised from its densely stellately hairy leaves, and the seeds are appendaged with a small scale and a filiform process. *Mollugo Cerviana*, Ser., is very conspicuous on account of its numerous filiform branches and narrow leaves in whorls.

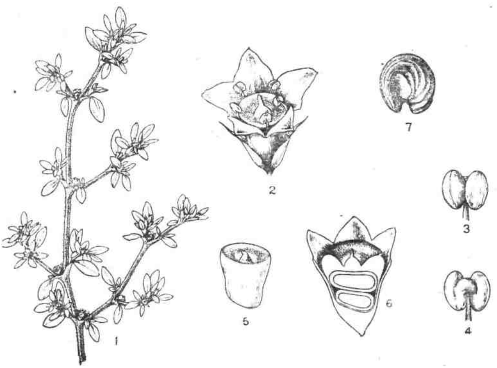

FIG. 315. *Trianthema crystallina*, Vahl. 1, branch ; 2, flower ; 3, anther front ; 4, anther back ; 5, fruit ; 6, fruit cut longitudinally ; 7, seed.

Characters of the Order.—All the plants of the family are herbs, annual or perennial. Leaves are simple, fleshy, opposite, alternate or falsely whorled. Flowers solitary or cymose, bisexual and without petals. Calyx is five-lobed. Stamens are definite or indefinite. Ovary is superior, two to five-celled. Fruit is a capsule with circumcissile or dorsal

dehiscence. Seeds, small, reniform, compressed, with endosperm.

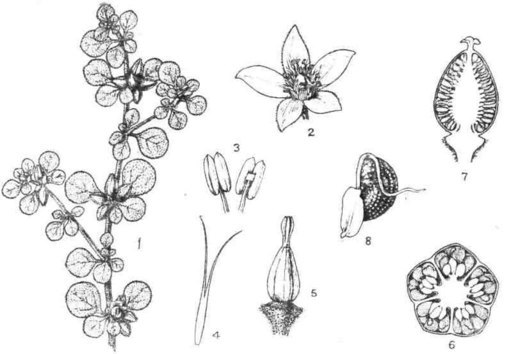

FIG. 316. *Mollugo hirta*, Thunb. 1, branch ; 2, flower ; 3, stamens ; 4, staminode ; 5, pistil ; 6, fruit cut across ; 7, fruit cut vertically ; 8, seed with appendage.

RUBIACEÆ.

In *Morinda tinctoria*, Roxb., we have a good example of this order. It is a small tree with thick white irregularly

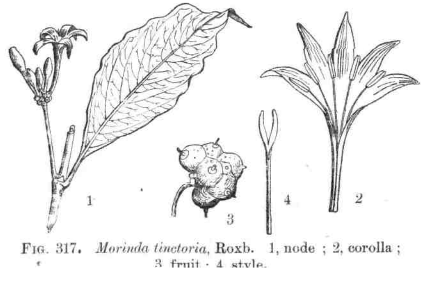

FIG. 317. *Morinda tinctoria*, Roxb. 1, node ; 2, corolla ; 3, fruit ; 4, style.

furrowed bark and crooked branches and young branches triquetrous. Leaves are opposite, simple, shortly petioled with connate interpetiolar stipules : the leaf blade is glabrous, elliptic or elliptic oblong, with entire margin and an acute or subacuminate apex.

Flowers are white and are collected together in heads borne by long peduncles that are leaf-opposed. The calyces of all the flowers are fused together, only a small portion at the top being free. The corolla is superior, tubular with five lobes. Stamens are five, epipetalous and included.

The fruit is globose, fleshy and it consists of the fused enlarged calyces of all the flowers, with many one-seeded drupelets or pyrenes. Seeds have endosperm.

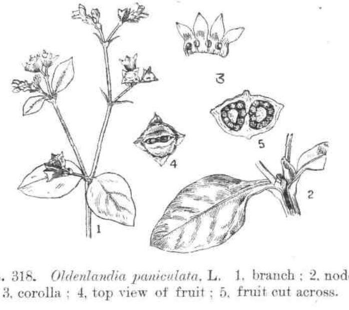

FIG. 318. *Oldenlandia paniculata*, L. 1, branch ; 2, node ; 3, corolla ; 4, top view of fruit ; 5, fruit cut across.

Oldenlandia umbellata, L., is a common herb of this family which may be examined next. This is an annual with numerous branches and linear, sessile, opposite leaves. The interpetiolar stipules are cut into bristles. Flowers are borne by long axillary peduncles, as cymose umbels. Flowers are tetramerous, and the ovary is inferior, two-celled, with numerous ovules. Fruit is a globose capsule with persistent distinct calyx teeth on its top. Seeds are small and many.

Other species of common occurrence are the following :—
Oldenlandia paniculata, L., *O. aspera*, DC., *O. Heynei*, Br.,

Randia dumetorum, Lamk., *Canthium parviflorum*, Lamk., and *Spermacoce hispida*, L. *Randia dumetorum*, Lamk., has large white flowers on short branches and it is a shrub armed with decussate spines and has large ovoid or ellipsoid fruits. *Canthium parviflorum*, Lamk., is a low shrub with sharp axillary spines, met with everywhere in scrubby jungles and waste places. Flowers of this plant are greenish white and the fruit is a didymous orange-yellow drupe. One of the most widely distributed weeds of the cultivated land is *Spermacoce hispida*, L. It is a prostrate herb with roughly hairy quadrangular stems and flowers are clustered at the nodes within the stipular cup. The fruit is a hairy capsule with two dark brown plano-convex seeds.

Characters of the Order.—This is a tropical family and it has many species (about 4,000). The plants of this order consist of trees, shrubs and herbs, and vary very much in their habit. Leaves are opposite or whorled, simple with interpetiolar stipules. Flowers are regular, tetra or pentamerous with an inferior two-to-ten-celled ovary. Fruit may be a berry, capsule or a drupe. Plants of this family are easily recognised by the interpetiolar stipules, opposite leaves and the inferior ovary.

COMPOSITÆ.

The common weed *Tridax procumbens*, L., introduced into India from South America is widely distributed and so, it may be selected as a representative of this large family.

This plant is a perennial herb with hairy straggling branches, some of them ending in heads. Leaves are opposite, simple ovate or ovate lanceolate with irregularly toothed margins and an acute apex and is covered with scattered hairs on both sides. Heads are solitary on long peduncles, heterogamous and rayed. The receptacle is flat or convex and it is paleate. The outer involucral bracts are hairy outside and shorter than the inner membranous ones. The ray flowers are all female with light yellow, or cream-white ligulate corollas that are deeply three partite. The disc flowers are all bisexual and tubular. The calyx is represented by a pappus which consists of feathery bristles. The corolla is bell-shaped and five-lobed. Stamens are five, epipetalous and

the anthers are syngenesious, sagittate with "short acute auricles" at the base of the lobes. Ovary is inferior, one-celled and one-ovuled and style arms of the tubular flowers are hairy only on the inner and upper surface. Fruit is an oblong achene, silkily hairy and crowned by the persistent feathery bristles of the pappus.

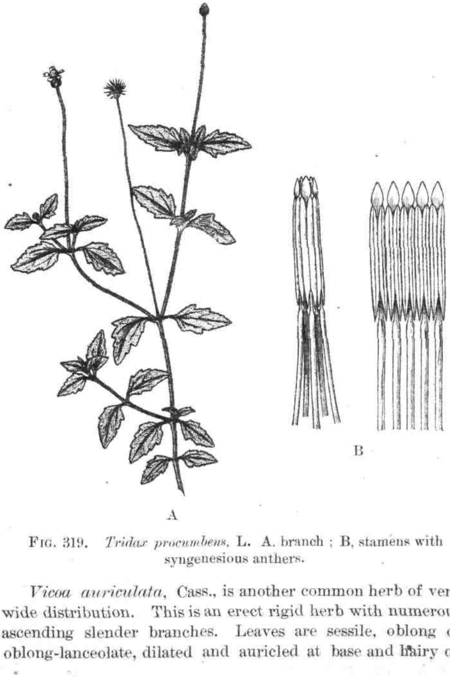

FIG. 319. *Tridax procumbens*, L. A. branch ; B, stamens with syngenesious anthers.

Vicoa auriculata, Cass., is another common herb of very wide distribution. This is an erect rigid herb with numerous ascending slender branches. Leaves are sessile, oblong or oblong-lanceolate, dilated and auricled at base and hairy on

both sides. Heads are heterogamous, rayed and on long peduncles. Involucral bracts are many-seriate, slender, linear, membranous, the outer being shorter. The receptacle is flat, epaleate. Corollas of the ray flowers are ligulate: ligule yellow, long, three-toothed at the free end, and that of the disc flowers are tubular. Anthers are syngenesious and bear tails at the base of the lobes. Achenes are small, covered with scattered hairs and have pappus hairs (no pappus hairs in the achenes of ligulate florets).

Vernonia cinerea, Less., is another herb of very wide distribution. The leaves of this plant are very variable in shape and hairiness. Heads are homogamous, small and are in lax terminal corymbs. All the flowers in a head are tubular and the involucre bracts are in many series, linear lanceolate, awned. Corolla of the tubular flowers is pink. The achenes are clothed with short white hairs and have two rows of pappus hairs.

Many species of Blumea are also found widely distributed in South India. *B. amplectens*, DC., *B. bifoliata*, DC., and *B. Wightiana*, DC., are quite common. The flower-heads in Blumea are heterogamous, anthers have tailed bases and the pappus is one-seriate. In wet situations *Eclipta alba*, Hassk., is sure to be found. The heads in this plant are heterogamous and the achenes of the disc are all thick and they are covered with some kind of excrescences.

Lactuca Heyneana, DC., is a troublesome weed of the waste places and it is easily recognised by the pinnatifid radical leaves, and the numerous erect branches terminating in long cylindrical narrow heads which consist of all ligulate flowers. Another weed, a native of America, now found in South India is *Lagascea mollis*, Cav. It is a slender, softly hairy herb, gregarious in habit and the heads are compound consisting of clusters of small heads. Flowers are all tubular.

Xanthium Strumarium, L., is another troublesome plant growing in beds of tanks and paddy fields when they lie fallow. Flowers are monœcious. The heads are either of hermaphrodite flowers (then they are sterile) or of female flowers which are always fertile. The female head consists of two flowers. The fruit is two-beaked and it consists of

two achenes completely within the involucral bracts grown and covered with prickles.

Characters of the Order.—This family embraces over 9,000 species and is one of the largest among the flowering plants, and it is widely distributed throughout the world.

All the members of this family are herbs and shrubs, with usually exstipulate, alternate (rarely opposite) leaves. Flowers small, sessile on the dilated end of the peduncle and enclosed by bracts (involucres). The heads may consist of all tubular bisexual flowers or the ray flowers may be ligulate and female or neuter, and the disc flowers tubular. Calyx tube is adnate to the ovary and the upper free portion is *either absent or it consists of pappus hairs or bristles.* The corolla is epigynous, ligulate in ray and tubular in disc flowers. The tubular corolla is bell-shaped, five-lobed and lobes have marginal veins. Stamens are five, epipetalous, with syngenesious anthers and free filaments, anther lobes may be tailed or not at the base and the connective is usually produced upwards. The ovary is inferior, one-celled and one-ovuled. Fruit is an achene crowned by the pappus. Seed erect and without endosperm.

The plants of this order are widespread and they are very aggressive and successful in occupying the land. The compact head, the easy accessibility of the honey to many kinds of insects and the pappus bearing achenes account for this.

SAPOTACEÆ.

Bassia longifolia, L., will serve as a type for this family. It is a large tree abounding in milky juice and the leaves are clustered near the ends of branches. Leaves are simple, alternate, stipulate, with linear-lanceolate, entire, acute, glabrous blades.

Flowers are clustered like the leaves at the ends of branches. The calyx consists of four sepals in two whorls, the outer two enclosing the two inner. Corolla is fleshy and six to twelve-lobed, campanulate. Stamens are epipetalous, sixteen to twenty in two rows one above the other; anthers are lanceolate with connectives produced above. Ovary is densely clothed with fine hairs and six or more-celled. Style is long

Fruit is a berry, somewhat round or oblong with one or two seeds. Seeds have brown polished testa and endosperm.

Two species of Mimusops are fairly common: *M. Elengi* L., is grown as an ornamental tree and *M. hexandra*, Roxb., is found growing wild in all scrubby jungles and low hills. The flowers of Mimusops have staminodes and the calyx consists of six or eight lobes.

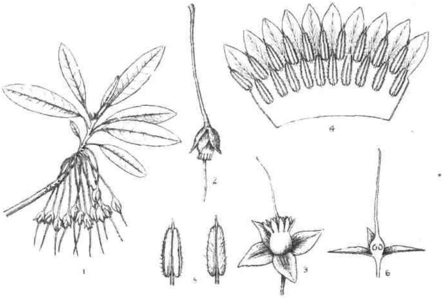

FIG. 320. *Bassia longifolia*, L. 1, branch; 2, flower bud; 3, open flower; 4, corolla and stamens; 5, anthers; 6, pistil.

Bassia malabarica, Bedd., is very common on the West Coast, and differs from the other Bassia in having a corolla, hairy both in and out, a glabrous ovary, and lanceolate fruit which is glabrous.

Characters of the Order.—All the members of this family are trees, abounding in milky juice. Leaves are thick, and clustered near the ends of branches. They are simple, alternate, and usually exstipulate (if stipulate, stipules are small and they fall away very soon). Flowers are small, regular, bisexual, axillary and crowded at the ends of branches. The calyx is four to eight-lobed and the corolla is monopetalous with twice or four times the number of calyx segments. Stamens vary in number from twelve or sixteen to forty, one, two, or three-seriate: staminodes are present in some genera. Ovary is superior, two to eight-celled, but with solitary ovules in each. Fruit is a berry with one to

eight seeds. Seeds are ellipsoidal, usually with a polished testa and a long hilum and without endosperm.

APOCYNACEÆ.

The widely distributed spiny ever-green *Carissa spinarum* L., will serve as a type. It is a low spreading shrub abounding in milky juice and with zigzag branches branching in a cymose manner and bearing bifurcating sharp spines. The leaves are opposite, exstipulate, short petioled oblong or oblong-elliptic coriaceous and glabrous (though sometimes slightly hairy).

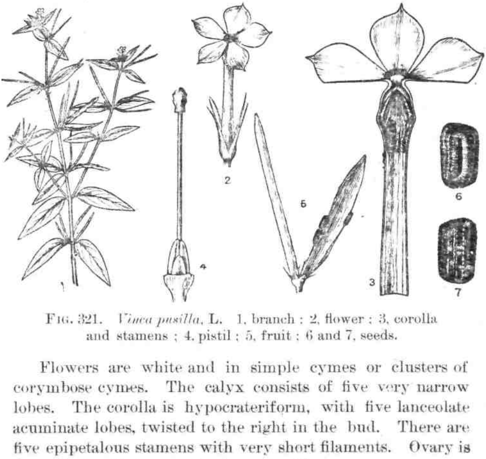

FIG. 321. *Vinca pusilla*, L. 1, branch : 2, flower : 3, corolla and stamens ; 4, pistil ; 5, fruit ; 6 and 7, seeds.

Flowers are white and in simple cymes or clusters of corymbose cymes. The calyx consists of five very narrow lobes. The corolla is hypocrateriform, with five lanceolate acuminate lobes, twisted to the right in the bud. There are five epipetalous stamens with very short filaments. Ovary is two-celled with two ovules in each cell.

Fruit is a berry with four seeds, dark purple when ripe.

Vinca rosea, L., is a garden plant grown everywhere and it differs from the above in some respects. Flowers arise in pairs from the axils of leaves and the corolla is hypocrateriform, white or pink in colour. Calyx consists of five very

narrow lanceolate lobes. The corolla tube is slightly swollen at the throat just below the attachment of the limbs. Stamens are five, inserted on the tube just in the dilated portion of the tube. Filaments are very short and the anthers just lying close to the stigma, but free from it. Ovary consists of two free carpels and there are two glands alternating with the carpels : style is long, filiform but the stigma is large, drum-shaped, or hour glass shaped, with a hyaline frill at the base all round. The fruit consists of two follicles with small rugose black seeds.

Vinca pusilla is a weed resembling *Vinca rosea* very much in all its parts, but only smaller.

Wrightia tinctoria, Br., is a small deciduous tree with milky juice. Flowers are white and in terminal diffuse dichotomous cymes. The corolla has fimbriate scales and five sagittate anthers united so as to form a column adhering to the stigma. The fruit consists of two follicles having linear hairy comose seeds.

Nerium odorum, Soland., is another shrub very commonly grown for its flowers. Leaves are in whorls of three, lanceolate and the flowers are pink and in terminal panicles or irregular dichotomous cymes. Both the corolla and the connective have appendages. Fruit consists of two follicles and seeds are hairy and comose.

Characters of the Order.—The members of this family are trees, shrubs (erect or climbing) and herbs. They usually contain a milky juice. Leaves are simple, opposite or whorled and entire. Flowers are regular, bisexual and in cymes. The calyx is deeply five-toothed and the lobes are imbricate in bud. Corolla is tubular, rotate or hypocrateriform, five-lobed and lobes twisted. Stamens are five, epipetalous, with very short filaments ; anthers are usually sagittate. Ovary is usually two-celled, united or separated into carpels. Fruit is a berry or a follicle. Seeds are with coma or wing, or without these.

ASCLEPIADEÆ.

Calotropis gigantea, R. Br., is a member of this order This plant is a shrub foun l all over the country, and abounds

in milky juice. The whole plant is covered with appressed white cottony tomentum, which can easily be rubbed off. Leaves are large, opposite, exstipulate, sessile or very shortly petioled, elliptic-oblong to obovate-oblong, thick, entire and the base narrow or cordate.

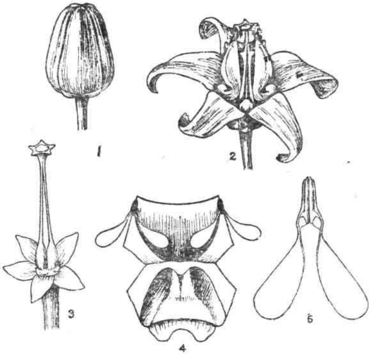

FIG. 322. *Calotropis gigantea*. R. Br. 1, flower bud ; 2, flower ; 3, pistil ; 4, anther ; 5, pollinium.

Flowers are large purple or bluish pink and arranged in lateral umbles ; pedicel is fine and covered with cottony wool. The calyx is five-partite, and the segments are short and triangular. The corolla is rotate, five lobed ; lobes are broadly triangular, acute and valvate in bud. The stamens are united so as to form a column and this column has five coronas in the form of laterally compressed thick plates ; anthers are broad, membranous, united with the pentagonal stigma. Pollen is massed together as pollen masses, and each anther-cell has a single pendulous pollinium. The ovary is two-celled, carpels are free with free styles, but with a large single pentagonal stigma.

The fruit consists of a single large follicle (very rarely two) containing comose flat seeds.

Some of the members of this family are met with in thickets and hedges as twiners. For instance *Dæmia extensa*, Br., is a frequently seen twiner with flowers having both corolline and staminal coronas, and follicles covered with soft spines. *Leptadenia reticulata*, W & A., is another coarse climber with clear or slightly yellow acrid juice, and opposite, glabrous coriaceous leaves. The flowers have both corolline and staminal coronas, and the petals have a small hairy process at their tips on the inner face.

The genus Ceropegia is a very striking one on account of its corolla, which is tubular, inflated below and above, but ending above in five lobes which cohere in different ways.

There are a number of plants of this order that have adapted themselves to a xerophytic life. The genus Hoya has very fleshy leaves and the species thrive even under very dry conditions. *Sarcostemma brevistigma*, W & A.; *Boucerosia umbellata*, W & A., and *Caralluma adscendens*, Br., have very fleshy green stems without leaves and, even when developed, they appear when young as small scales and then drop off. The first one is a creeper with a leafless cylindrical green stem and white flowers in umbels, and the other two are small plants with very succulent square green stems and large flowers.

Characters of the Order.—This is a large order consisting mostly of twining shrubs and herbs with a milky juice. Leaves are opposite, exstipulate, and simple. Flowers are regular, symmetrical, pentamerous and in umbels. The calyx is usually divided down to its base into five small segments and the corolla is five-lobed, rotate or tubular and in some genera provided with corona. Stamens are five and the filaments are united so as to form a fleshy tube and with outgrowths at the back (corona); anthers are free or united to the stigma; pollen grains are found in masses (pollinia) and each pollinium may have a stalk (caudicle) and a gland (corpuscles).

The ovary is superior of two one-celled free carpels; ovules are many. Fruit consists of two follicles, but often only one is developed, and seeds are flat and comose.

BORAGINEÆ.

The two plants *Trichodesma indicum*, Br., and *Heliotropium ovalifolium*, Forsk., are typical examples of the family.

Trichodesma indicum, Br., is a low annual with many hispid branches, flourishing in dry situations. Leaves are simple, opposite and also alternate, sessile, exstipulate, linear-oblong or oblong-lanceolate, entire and cordate at base; the upper surface is covered with stiff hairs springing from tubercles that appear as white circles when dry and the lower surface is more hairy, but less harsh.

FIG. 323. A branch of *Trichodesma indicum*, Br.

Flowers are solitary, leaf-opposed, with pale blue corollas. The calyx is deeply five-lobed, covered with long stiff hairs and grows in the fruit; the lobes are lanceolate, acute and prolonged at the base and hence hastate or auricled. The corolla consists of a short tube and five spreading lobes that are somewhat ovate triangular in shape; the lobes have a brown patch at their bases and end in pointed processes which are short or long (then twisted). Stamens are five, epipetalous, with very short filaments; the anthers are oblong or lanceolate and united into a cone and are hairy outside; the connectives are broad outside,

produced beyond the apex and are twisted together. Ovary is four-lobed and four-celled with a single ovule in each and the axis is very prominent. Style is long.

The fruit is conical, and the four lobes separate from the axis as nutlets, leaving four pits : the nutlets are grey and smooth at the back and the inner surface is rugose.

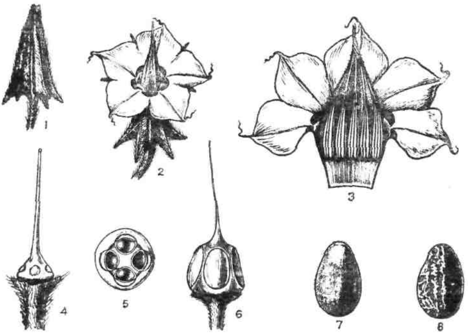

FIG. 324. *Trichodesma indicum*, Br. 1, flower bud ; 2, open flower ; 3, corolla and stamens ; 4, pistil ; 5, pistil, transverse section ; 6, fruit ; 7, back of nutlet ; 8, inner-face of nutlet.

Heliotropium ovalifolium, Forsk., is a herbaceous plant with numerous softly hairy, prostrate or erect branches flourishing in clayey soils, such as the beds of tanks and paddy fields when they lie fallow. Leaves are alternate, simple, exstipulate, shortly petioled, obovate or elliptic, and softly densely hairy on both sides. Flowers are white, small and are two ranked on one side of an axis, which is really a scorpioid cyme ; and this is why the inflorescence is coiled at the free end. The calyx is persistent in fruit, five-partite and one lobe is very much larger than the other four ; corolla is tubular, hairy outside and also with a few hairs at the throat Stamens are five, epipetalous ; filaments are very short and the anthers are lanceolate. The ovary is four-

celled and four-ovuled. There is no style and the stigma is conical with a few hairs at the top. The fruit breaks into four nutlets.

Other species of Heliotropium occurring in South India are *H. indicum*, L., *H. supinum*, L., and *H. marifolium*, Retz.

FIG. 325. *Heliotropium ovalifolium*, Forsk

Coldenia procumbens, L., is a diffuse prostrate herb usually found in paddy fields, easily recognised by the branches which are lying quite flat on the ground with crisped hairy leaves and solitary axillary flowers.

Some members of this family, *Cordia Myxa*, L., *C. monoica*, Roxb., and C. *Rothii*, R & S., are small deciduous

trees commonly met with in the forests of the plains and low hills. The fruit of Cordia is a drupe with gummy pulp.

Ehretia buxifolia, Roxb., is a very common shrub growing in scrubby jungles of the plains.

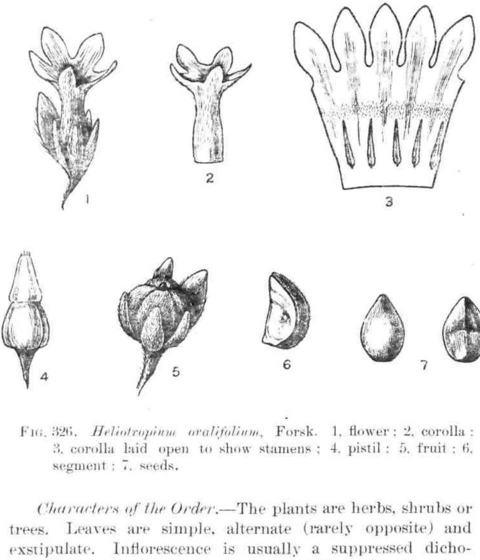

FIG. 326. *Heliotropium ovalifolium*, Forsk. 1, flower; 2, corolla; 3, corolla laid open to show stamens; 4, pistil; 5, fruit; 6, segment; 7, seeds.

Characters of the Order.—The plants are herbs, shrubs or trees. Leaves are simple, alternate (rarely opposite) and exstipulate. Inflorescence is usually a suppressed dichotomous cyme. Flowers are regular and bisexual. The calyx is five-partite, persistent, the corolla is tubular, five-lobed. Stamens are five with short filaments, epipetalous. Ovary is two to four-celled with one ovule in each cell. Fruit is either a drupe or it divides into four nutlets.

This order is a cosmopolitan one with many species widely spread in temperate climates and in the tropics.

CONVOLVULACEÆ.

The small herb *Evolvulus alsinoides*, Wall., growing amidst grass in waste places may be chosen as a type. This is a perennial and produces numerous wiry stems covered

FIG. 327. *Convolvulus arvensis*, L.

with long, soft hairs. Leaves are small, alternate, exstipulate, variable, elliptic oblong and densely clothed with soft adpressed hairs on both sides. Flowers are solitary, peduncle jointed. The calyx consists of five, narrow free sepals densely covered with silky hairs. The corolla is rotate, blue. Stamens are five, epipetalous. Ovary is superior, two-celled and four-ovuled ; Styles are two, distinct and bifid at the tip.

Fruit is a globose four-valved capsulé containing four glabrous seeds.

The genus Ipomœa is quite characteristic of this family and any one of its numerous species may be examined. Most of these are twiners and a few are prostrate ones. The calyx is of five unequal, free sepals (quincuncially) imbricate and, in some, enlarged in fruit. The corolla is monopetalous, funnel or bell-shaped and the lobes are plicate and this is well seen even in an open flower. Stamens are five, equal or unequal, epipetalous; filaments in some dilated at base. Ovary is two or four-celled and four-ovuled; style is filiform with a bi-globose stigma. Fruit is capsular, four-valved and four-seeded. Seeds are smooth, velvety, or even hairy.

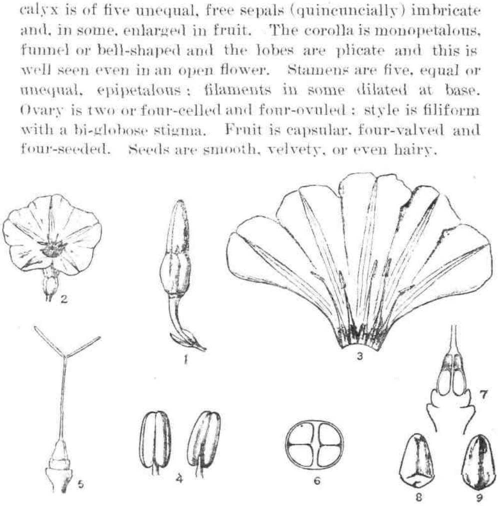

FIG. 328. *Convolvulus arvensis*, L. 1, flower bud; 2, flower; 3 corolla laid open to show stamens; 4, anthers; 5, pistil; 6 transverse section of fruit; 7, longitudinal section of ovary; 8 and 9, seeds.

Convolvulus arvensis, L., and *C. Rottlerianus*, Chois., are also very common in certain regions. The former is a low twiner with underground branches and it is a persistent weed. Its flowers and fruits are like those of Ipomœa, but the stigmas are elongate instead of bi-globose.

The parasitic plants *Cuscuta reflexa*, Roxb., and *C. chinensis*, Lamk., are members of this family.

Characters of the Order.—These are herbs or shrubs, mostly twining, though a few are erect. Leaves are simple, alternate, exstipulate, and petiolate. Flowers are in cymes or solitary, regular and bisexual. The sepals are five, free and imbricate. The corolla is usually showy, rotate, bell-shaped or funnel-shaped. Stamens are five, unequal and epipetalous. The ovary is superior, two or four-celled with four ovules. Fruit is a capsule. Seeds are with scanty endosperm, and folded foliaceous cotyledons.

This is another order cosmopolitan in its distribution, though abundant in the warmer regions.

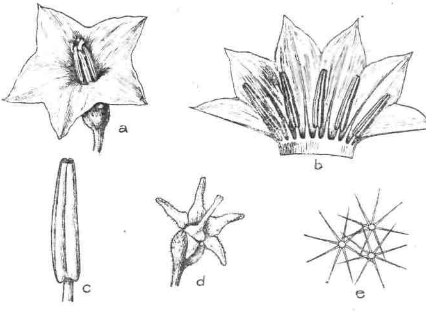

FIG. 329. *Solanum Melongena*, L. *a*, flower ; *b*, corolla and stamens *c*, anther ; *d*, pistil and calyx ; *e*, stellate hairs.

SOLANACEÆ.

The widely cultivated brinjal plant *Solanum Melongena*, L., is a good type of the family. This plant grows to a height of three to six feet and the whole plant is thickly coated with stellate hairs, and it is also armed with prickles. Leaves are alternate, exstipulate, petiolate, ovate sinuate or lobed

covered below with stellate hairs and with prickles on the veins, and unequal at base.

Flowers are in extra-axillary helicoid cymes, only one flower being perfect. The calyx is five-lobed, stellately hairy outside, and it is persistent and grows with the fruit and sometimes also prickly. Corolla is violet blue, rotate, five-lobed (sometimes six to eight), stellately hairy outside between the folds and on the plaits. Stamens are equal to the corolla lobes, epipetalous; filament is short, and anthers are long and open by apical pores. Ovary is superior, two-celled and many ovuled.

Fruit is a two-celled berry with many compressed flat seeds.

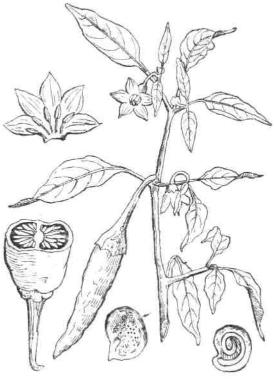

FIG. 330. *Capsicum frutescens*, L.

This plant exhibits certain amount of variation in its flower under cultivation. On the same plant we find corollas with five, six, seven or eight lobes and as many stamens. The fruit shows many irregular cavities due to unequal growth and development of the placenta.

Solanum xanthocarpum, Schrad and Wendel., is a very prickly plant with diffuse branches very much like the Brinjal plant in the structure of its flowers, but the fruits are smaller.

Solanum torvum, Sw., is a shrub without prickles and the flowers are white.

Solanum nigrum, L., is also a common plant easily recognised by the extra axillary umbellate cymes of red or black round berries. The berries are sweet and are eaten in this country, but they are said to be highly poisonous in England.

Capsicum frutescens, L., and *C. annum*, L., and *Nicotiana Tabacum*, L., are under cultivation. In all these, the anthers dehisce longitudinally and the fruit is a berry in the first two and a capsule in the third.

Physalis, Withania and Nicandra have persistent enlarged membranous calyces covering the fruit.

Characters of the Order.—The members of this family are either herbs or shrubs. Branches in some species are sympodial. Leaves are alternate, simple, petiolate and exstipulate. Flowers are regular, pentamerous and bisexual and in extra axillary or lateral cymes. The calyx is inferior five-lobed, persistent and even accrescent. The corolla is monopetalous, rotate or funnel shaped, with five lobes. Stamens are five, epipetalous with very short filaments and anthers dehiscing by apical pores or longitudinally. Ovary is superior, two-celled. Fruit is a berry or a capsule. Seeds are without endosperm, usually compressed.

ACANTHACEÆ.

The common weed *Ruellia prostrata*, Lamk, is a good example of this family. It is a much branched herb, with long internodes and nodes slightly thickened and purple. Leaves are opposite, exstipulate, petiolate, ovate entire, sparsely hairy on both sides.

Flowers are solitary, axillary, sessile, with two bracteoles. The calyx is divided to its base into five very narrow segments. The corolla is violet pink, monopetalous, tubular below, and funnel-shaped above, with five rounded lobes

twisted in bud to the left, but spreading out in open flower. The stamens are epipetalous, didynamous. The ovary is superior, two-celled and many-ovuled with axile placentation; style long and hairy, stigma bifid but one lobe is very short.

The fruit is a capsule somewhat club-shaped with a mark at the tip which, if wetted, brings about the dehiscence. Seeds are thin, discoid on hard funicles (retinacula) and there is a line of hairs at the margin.

FIG. 331. *Rungia parviflora*, Nees.

Rungia parviflora, Nees, is another plant met with in the bunds of paddy fields and ditches, amidst grass. It is a branched herb with slender glabrous branches. Flowers are in one-sided spikes with bracts and bracteoles. The bracts

without flowers are larger than those connected with the flowers and both the bracts have scarious margins. The corolla is two-lipped with two epipetalous stamens. The anther lobes are placed one above the other and the lower lobe has an appendage. The fruit is a small compressed capsule.

Hygrophila spinosa, T. Anders., is another, common stout, erect herb with many straight branches bearing long spines at the nodes, growing in moist situations such as ditches amidst paddy fields.

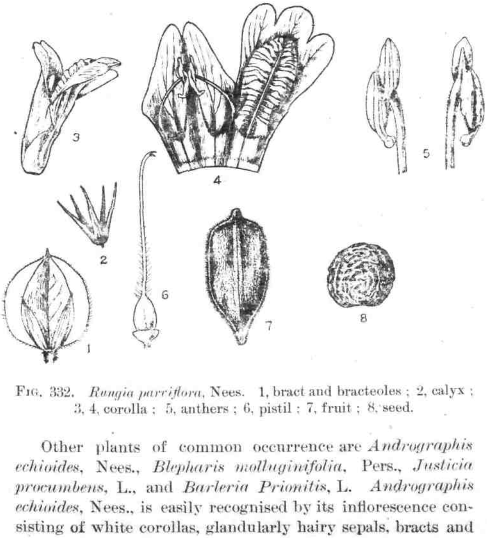

FIG. 332. *Rungia parviflora*, Nees. 1, bract and bracteoles; 2, calyx; 3, 4, corolla; 5, anthers; 6, pistil; 7, fruit; 8, seed.

Other plants of common occurrence are *Andrographis echioides*, Nees., *Blepharis molluginifolia*, Pers., *Justicia procumbens*, L., and *Barleria Prionitis*, L. *Andrographis echioides*, Nees., is easily recognised by its inflorescence consisting of white corollas, glandularly hairy sepals, bracts and bracteoles; *Blepharis molluginifolia*, Pers., has wiry prostrate branches with whorled leaves and solitary flowers with three or four pairs of decussating bracteoles and a corolla with a three-lobed lower tip and without the upper one. In *Justicia*

the flowers are small and in terminal spikes and *Barleria Prionitis* is conspicuous by its regular orange tubular corollas with two stamens and axillary spines.

Characters of the Order.—Plants of this order are herbs or shrubs. Leaves are opposite, exstipulate, simple and the nodes are somewhat swollen. Flowers are hermaphrodite, regular or irregular, in cymes, spikes or racemes with bracts and bracteoles. The calyx is usually deeply five-lobed and the corolla equally or unequally five-lobed. Stamens are four or two, epipetalous; anther lobes parallel and near or superposed. Ovary is superior two-celled and many-ovuled. Fruit is a loculicidally dehiscing capsule. Seeds are many or few, discoid, compressed, smooth or hairy, seated on retinacula (hardened funicles), and there is no endosperm.

LABIATÆ

The common weed, *Leucas aspera*, Spreng., will serve as a good example of this family.

This is a diffusely branching annual with hairy, square stems. The whole plant possesses a strong smell. Leaves are exstipulate, opposite, sessile or with a very short petiole, linear, coarsely crenate and hairy on both the surfaces.

Flowers are sessile and collected together in congested cymes (verticillasters) in the axils. Bracts are linear, acute with long hairs on the margins. The calyx is monosepalous, persistent, tubular, bent and constricted below; the upper portion of the tube is ribbed and hairy, but the lower half is glabrous and membranous; the mouth of the tube is oblique, with the small upper teeth projecting above. The corolla is white and labiate; the upper lip is narrow and very densely woolly outside, and the lower lip is broad, flat, three-lobed, the midlobe being the largest and obovate and the lateral smaller. The stamens are epipetalous, didynamous and included within the upper lip; anthers are red. The ovary is superior, deeply four-lobed and is surrounded by a lobed-disk. The style is long and it rises from the middle of the four lobes (gynobasic).

The fruit consists of four oblong nutlets, rounded at the back and angled inside.

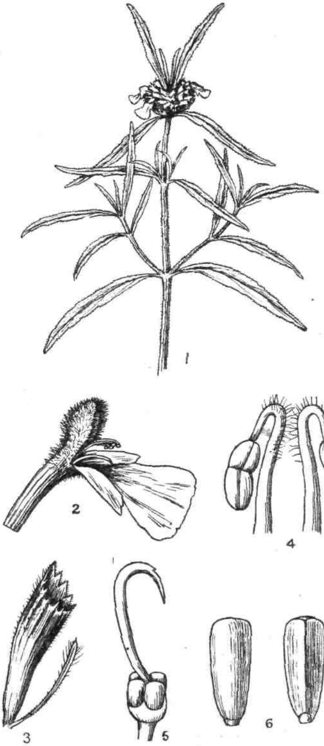

FIG. 333. *Leucas aspera*, Spreng. 1, branch ; 2, corolla ; 3, calyx and bract ; 4, stamens ; 5, pistil ; 6, nutlets.

Other plants that are easily procurable are *Ocimum canum*, Sims., *O. sanctum*, L., O. *Basilicum*, L., and *Anisomeles malabarica*, R. Br. All these plants are aromatic. The Ocimums have a labiate corolla with the upper lip broader and four-lobed and a narrow lower lip, and the two-upper stamens have hairy appendages at their base. *Anisomeles malabarica*, R. Br., is a very softly woolly plant with a large, pinkish, two-lobed corolla and the flowers are in distant cymes.

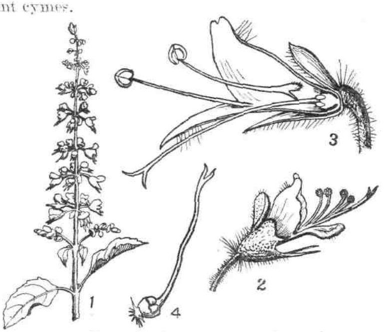

FIG. 334. *Ocimum sanctum*, L.
1, branch ; 2, flower ; 3, section of flower ; 4, pistil.

The species *Moschosma polystachyum*, Benth., is a glabrous plant often met with in wet places, and it is easily recognised by its one-sided whorled inflorescence. Many species of Leucas occur both on the plains and on the hills. In some parts of the Presidency the plant *Leonotis nepetæfolia*, R. Br., is a very conspicuous plant. It has got very large verticillasters, and the corolla is scarlet or deep orange.

Characters of the Order.—The members of this family are mostly scented herbs though a few are shrubby. The axis is quadrangular and hairy. Leaves are exstipulate, opposite or whorled. Flowers are bisexual, irregular, labiate, in cymes or in false whorls (verticillasters). The calyx is monosepalous, persistent, regular or irregular. The corolla is

tubular, labiate. The stamens are epipetalous and didynamous or all four equal and all or only two perfect. The ovary is superior with a lobed disk and a two-fid long slender style, which is apical or gynobasic. *Fruit consists of four nutlets.*

AMARANTACEÆ.

Achyranthes aspera, L., growing in hedges and thickets all over South India is a representative of this family.

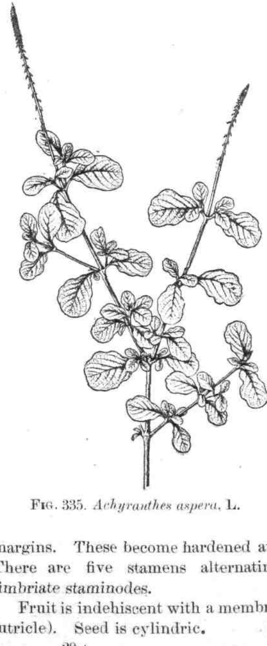

FIG. 335. *Achyranthes aspera*, L.

This plant produces only a few straggling branches and the axis is *rounded and striate*. Leaves are exstipulate, simple, opposite, petioled, obovate or rotund and finely hairy on both sides, and margins entire wavy.

Flowers are in terminal spikes, stiffly deflexed and crowded on the axis. Both the bract and the bracteoles are ovate and spinescent, persistent and become hardened *in fruit*. The perianth consists of five ovate oblong or lanceolate, shining, glabrous sepals, that are greenish or reddish at the edges, with spinescent apex and membranous margins. These become hardened and persist with the fruit. There are five stamens alternating with five truncate, fimbriate staminodes.

Fruit is indehiscent with a membranous hardened pericarp (utricle). Seed is cylindric.

Amarantus viridis, L., *A. spinosus*, L., and *A. gangeticus*, L., are very common plants; the first two occur as weeds in waste places and the third is largely cultivated. The flowers are generally small, unisexual and monœcious.

Many plants of this order grow as weeds in the fields and he most common ones are the following: *Celosia argentea*, L. (most abundant in dry fields and very conspicuous on account of its glistening white spikes, pinkish at first) *Aerua lanata*, Juss., *A. javanica*, Juss., and *A. Monsonia*., Mart.

FIG. 336. *Amarantus viridis*, L.

In hedges and in thickets *Pupalia atropurpurea*, Moq., flourishes and it is easily recognisable from its inflorescence, in which the flowers are grouped in threes and the two lateral flowers become hooked spines, and remain attached to the middle one and persist with the fruit, resulting from the middle flower. *Alternanthera sessilis*, Br., is a plant found growing in damp places.

Characters of the Order.—All the members of this family are herbs. Leaves are exstipulate, simple, alternate or opposite. Flowers are hermaphrodite or unisexual, monœcious, in spikes or clusters. The perianth consists of five scarious persistent sepals. Stamens usually vary from one to five, and staminodes may be present or not. The ovary is one-celled and with one or many ovules that are erect or suspended from a funicle. Fruit is a membranous utricle.

Seeds usually orbicular, black polished and compressed; embryo coiled and in floury endosperm.

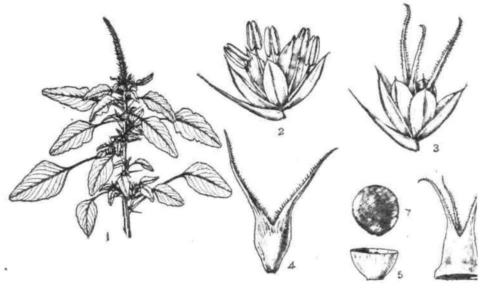

FIG. 337. *Amarantus spinosus*, L. 1, branch; 2, male flower; 3, female flower; 4, fruit, 5, base of utricle; 6, upper lid of utricle; 7, seed.

EUPHORBIACEÆ.

The order is a large one and the species differ very much in their vegetative parts and even in their flowers. Therefore it is necessary to select three types at least.

Acalypha indica, L., is a widespread common weed. It is an annual with numerous, long branches. Leaves are alternate, with very minute stipules, long petioled (the younger leaves short-petioled and older long-petioled), ovate serrate, three nerved at base.

Flowers are unisexual and monœcious, and in axillary elongated spikes. Male flowers are very minute and are clustered towards the apex of the spike, and the female flowers are few at the base, and at the apex of the inflorescence there is a peculiar appendage (a female flower), and sometimes this contains a seed. The male flowers have four sepals and eight stamens and the female flower is provided with a large, leafy many nerved, dentate bract. The ovary is hairy and three-celled with a single ovule in each cavity.

The fruit is a small hispid capsule and it is concealed by the enlarged bract. Seeds are ovoid, smooth and brownish.

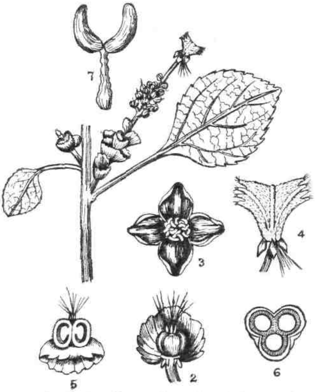

FIG. 338. *Acalypha, indica.* L. 1, branch : 2, female flower : 3, male flower : 4, terminal female flower : 5, fruit cut vertically ; 6, fruit cut across ; 7, a stamen.

Another common weed widely distributed is *Phyllanthus maderaspatensis*, L. This plant is a variable annual with numerous branches. In this plant, and also in some other species of Phyllanthus, the branchlets look like pinnate leaves. Leaves are small, alternate and bifarious, shortly petioled with lanceolate peltate stipules, obovate-cuneate, truncate or rounded at apex, often mucronate, and the nerves are conspicuous on the lower surface of the leaf.

Flowers are unisexual, monœcious ; male flowers are minute, sessile and clustered in the axils ; but the female flowers are larger, solitary and stalked. The sepals in both are six, obovate, with white margins. Stamens are three and the filaments are united. The ovary is superior three-celled with three two-lobed styles and two ovules in each cell.

The fruit is a capsule with three lobes. Seeds are somewhat trigonous though rounded at the back.

Euphorbia hirta, L., is an annual with erect or procumbent branches. The whole plant is covered with long rough hairs and it contains a milky juice. Leaves are opposite, short petioled and with pectinate stipules, obliquely elliptic or oblong-lanceolate, dentate, green, or reddish green.

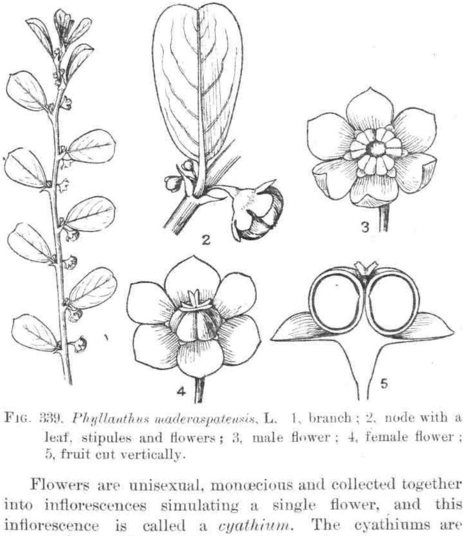

FIG. 339. *Phyllanthus maderaspatensis*, L. 1, branch; 2, node with a leaf, stipules and flowers; 3, male flower; 4, female flower; 5, fruit cut vertically.

Flowers are unisexual, monœcious and collected together into inflorescences simulating a single flower, and this inflorescence is called a *cyathium*. The cyathiums are crowded and axillary. The cyathium consists of a perianth-like organ or the involucre, which is tubular and five-lobed, a solitary fruit and a number of stamens within. The single fruit is really a female flower surrounded by a number of male flowers.

Each involucre consists of a tube, five very small limbs with minute glands between them. The stalked stamens found within the involucre and round a stalked ovary are really male flowers, each stalked stamen representing one flower. In every involucre there is a single stalked ovary which is a female flower.

Fruit is a capsule, three-lobed and covered with appressed hairs. Seeds are trigonous, transversely rugose and brown in colour.

There are many species of Euphorbias and they are easily recognised by their Cyathiums. *Euphorbia rosea*, Retz., and *E. corrigioloides*, Boiss., occur in dry open sandy situations. Some of the Euphorbias are big shrubs with cladodes and are typical xerophytes. *E. antiquorum*, L., and *E. tirucalli*, L., are examples.

The Castor plant (*Ricinus communis*, L.) *Jatropha Curcas*, L., *J. glandulifera*, L., *Phyllanthus emblica*, L., *P. reticulatus*, Poir., and *Flueggia Leucopyrus*, Willd., are other common plants of this order.

Characters of the Order.—The order includes herbs, shrubs and trees, and many of them abound in milky juice. Leaves are alternate or opposite, stipulate, petiolate, (sometimes petioles with glands), and usually simple. Flowers are small, unisexual, monœcious, and arranged in various ways. The perianth is usually single, rarely double. Stamens are few, many or even one. Ovary is superior three-celled with one or two ovules in each cavity. Fruits are capsules, berries or drupes. Seeds are often arillate, with endosperm.

URTICACEÆ.

The Jack-fruit and the Banyan tree are good examples of this order.

The Jack tree (*Artocarpus integrifolia*, L.) is a large evergreen tree with milky juice. Leaves are alternate, with large spathaceous, caducous stipules, oblong or elliptic oblong, shining and glabrous above, coriaceous.

Flowers are monœcious, in spikes or heads that are covered by large stipules when young. In the male spike the flowers have two oblong or spathulate sepals and a single stamen. The female flowers have a tubular perianth which is

united below to a concave receptacle, with the ovary at the bottom: the style is lateral. The female spike grows and becomes the fruit, but the male spike falls off.

The fruit consists of an enlarged axis covered with the very much accrescent fleshy perianths and carpels, with hardened flat spinescent apices. (See fig. 244.)

Ficus bengalensis, L., is a large spreading tree, capable of indefinite extension, on account of its aerial roots arising from the branches. All parts of the tree abound in milky juice and young parts are softly pubescent. Leaves are simple, alternate, stipulate, (stipules coriaceous and large), oblong or ovate-oblong, entire, obtuse, and three to seven nerved at base.

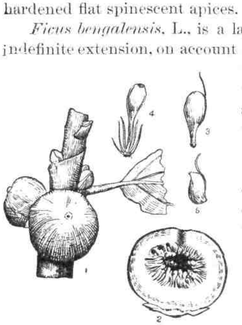

FIG. 340. *Ficus bengalensis*, L. 1. the inflorescence; 2. same cut vertically; 3. male flower; 4. gall flower; 5. female flower.

The fig or the young inflorescence consists of male, female and gall flowers lying inside the hollow receptacle, which is usually fleshy. There are many male flowers near the mouth of the receptacle, and each male flower has only one stamen and four sepals. The perianth in the gall flower is similar to that of the male flower. The female flower has four sepals shorter than in the male flower and the style is lateral.

Several species of Ficus are fairly common in South India and the most common ones are *Ficus religiosa*, L., *F. glomerata*, Roxb., *Ficus Tsiela*, Roxb., and *Ficus hispida*, L.f., and *F. asperrima*, Roxb.

The small gnarled tree *Streblus asper*, Lour., with its crooked interwoven branches, may be seen in scrubby jungles. Flowers are diœcious.

Dorstenia indica, Wall., is a small herb growing in damp situations on the hills and it is easily recognised by the flat receptacle with both kinds of flowers on it.

MONOCOTYLEDONS.

ORCHIDEÆ.

Eulophia virens, Brown, is an Orchid occurring in dry ground all over the Presidency.

This is a herbaceous, perennial, ground Orchid having a pretty large epigeal conical rhizome (pseudobulb) with long grass-like, plaited leaves possessing a strong midrib.

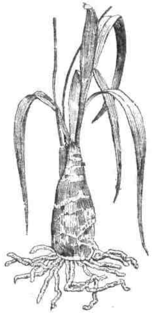

FIG. 341. *Eulophia virens*, Brown. An entire plant without inflorescence.

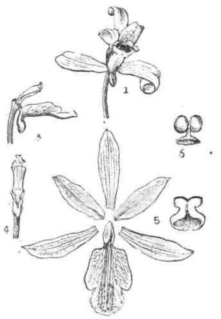

FIG. 342. *Eulophia virens*, Brown. 1, flower; 2, sepals and petals; 3, side view of lip and column; 4, front view of column; 5, anther; 6, pollinia.

Flowers are racemose on a lateral scape, and are hermaphrodite, showy and irregular; bracts are small and persistent. There are three sepals, all alike. Petals are three, but two are alike and the third is different in shape. It is three-lobed and adnate to the column and saccate at the base; the middle lobe is larger than the lateral lobes and bears inside four or five ridges of thread-like outgrowths (carinate); all the petals are green with red lines. The stamen is solitary and it is reduced to its anther, which is seated on the top of the column. The pollen grains are coherent into two oblong

masses, attached by a short strap to a discoid gland. The ovary is inferior, one-celled with three parietal placentas and the stigma is the concave face of the column below the anther.

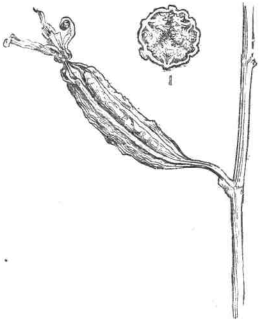
FIG. 343. *Eulophia virens*, Brown. 1, transverse section of fruit ; 2, fruit.

The fruit is a capsule. Seeds are extremely small with a lax hyaline testa.

Vanda Roxburghii, R. Br., is an epiphytic orchid growing on branches of trees with long stout aerial roots. The flowers of this orchid are large and showy. The two Habenarias *H. viridiflora*, R. Br. and *H. platyphylla*, Sprengl., occur in the plains. On the hills several species of Dendrobium, Cœlogyne, Aerides and Habenaria are usually met with.

Characters of the Order.—The members of this family are all herbs, growing in the ground or epiphytic. Shortened and variously thickened branches are possessed by some species and these are called pseudobulbs. Flowers are usually in spikes or racemes, bisexual, irregular, often showy. Perianth is superior and consists of two whorls, the outer consisting of three sepals, more or less similar and the inner whorl of petals, more or less dissimilar ; the two lateral petals are alike and resemble the sepals, but the lower petal, called the lip, is variously shaped. There is a single stamen, but it is reduced to an anther united in a column with the style.

The pollen grains are coherent into waxy and powdery masses, called pollinia and these are stalked and attached by it to a gland. The ovary is inferior and one-celled with parietal placentas. Fruit is a capsule and the seeds are very minute with lax hyaline testa.

This order is a very large one and the variations exhibited by the plants especially in the structure of its flowers are very great. However, the most striking character of all orchids is the presence of the lip and the column consisting of the combined stamen and style and the pollinia.

SCITAMINEÆ.

The plantain tree, *Musa paradisiaca*, L., may be studied as a type.

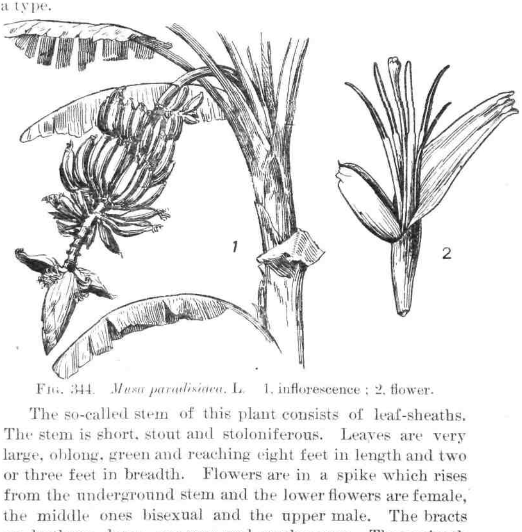

FIG. 344. *Musa paradisiaca*, L. 1, inflorescence ; 2, flower.

The so-called stem of this plant consists of leaf-sheaths. The stem is short, stout and stoloniferous. Leaves are very large, oblong, green and reaching eight feet in length and two or three feet in breadth. Flowers are in a spike which rises from the underground stem and the lower flowers are female, the middle ones bisexual and the upper male. The bracts are leathery, large, concave and spathaceous. The perianth is tubular, slit down on one side and five-toothed. The corolla is reduced to a single membranous petal. Stamens are five. The ovary is inferior, three-celled, and the style is filiform and rises from a thickened base. Fruit is a berry with only imperfect seeds.

The Turmeric plant (*Curcuma longa*, L.) the Ginger plant (*Zingiber officinale*, Roscoe), the Cardamoms (*Elettaria Cardamomum*, Maton) and *Canna indica*, L., are species of this family.

Characters of the Order.—The plants of this family are herbs, with rhizomes or stolons and the aerial stems consist, more or less, of the leaf-sheaths. Leaves are generally large, with sheathing leaf-stalks. The blade is usually large with a strong midrib and close set parallel secondary veins. Flowers are bisexual in most, though unisexual and polygamous in Musa. The perianth consists of two whorls. There are three sepals, free or connate. The petals also are three and they are free or tubular. There is only a single perfect stamen in many plants but there are five of them in Musa. Ovary is inferior, three-celled. Fruit is a berry or a capsule. Seeds are arillate (in some species) and the endosperm is floury.

AMARYLLIDEÆ.

The garden plant *Crinum asiaticum*, L., is a species of this family.

This plant is a herb with a large tunicated bulb. The bulb has a long stout neck. Leaves are very long and very broad, linear lanceolate, flat and with a sheathing base.

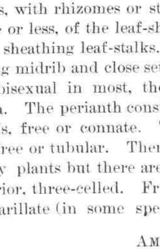

FIG. 345. A flower of *Crinum asiaticum*, L.

Flowers are large, showy and umbellate on a stout scape. Bracts are long. The perianth is tubular, white, fragrant at night, six-lobed, lobes linear-oblong. There are six stamens with versatile anthers. Ovary is inferior, three-celled, with many ovules in each.

Fruit is a capsule bursting irregularly. Seeds are few, large and rounded, with plenty of endosperm.

Curculigo orchioides, Gærtn., the Nilappanai, is another species very common in sandy situations. It has got a deep underground erect cylindrical stem with plicate lanceolate leaves

whose tips are sometimes viviparous. The flowers are small and bright yellow.

The Agaves, *A. americana* L., *A. vivipara L.*, largely planted along the railway lines for hedging, are members of this family.

Polyanthes tuberosa, L., or the Tuberose is largely grown in gardens throughout the Presidency. The flowers are white and are very fragrant.

Characters of the Order.—Most of the plants of this order are herbs. Stem is a bulb, or corm or an erect underground rootstock. Flowers are in umbels on a scape. Perianth is regular, biseriate, six-lobed or partite. Stamens are six, springing from the perianth lobes, and anthers versatile or erect. The ovary is inferior three-celled with many ovules. Fruit is inferior, capsular. Seeds with endosperm.

LILIACEÆ.

The climbing plant *Gloriosa superba*, L., bearing large scarlet, showy flowers and found growing in dry places both on the East and West Coasts, is a good example.

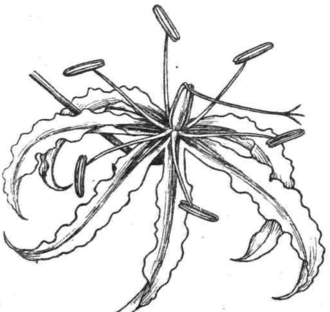

FIG. 346. A flower of *Gloriosa superba*, L.

This plant has underground stem-tubers, some of which have the shape of a country plough (hence the Tamil name Kalappai Kizangu) and the aerial branches spring from them. Leaves are alternate, opposite or whorled, sessile, lanceolate and the apex is modified into a tendril.

Flowers are large, solitary, axillary. There are six linear lanceolate perianth segments with wavy margins, green when young, then yellow and finally scarlet or deep orange. Stamens are six with versatile anthers. The ovary is superior, three-celled, with the style deflexed. The fruit is a capsule.

Asparagus racemosus, Willd., is a common climber with many tuberous or thickened fleshy roots, growing even in low forests. This is easily recognised by the spinous pointed cladodes, springing from the axils of minute scale-like leaves.

The Onion (*Allium Cepa*, L.) and the Garlic (*A. sativum*, L.) belong to this order.

The bulbous plants *Iphigenia indica*, A. Gray, and *Scilla indica*, Baker, are fairly common in dry sandy places. *Urginea indica*, Kunth, is a common bulb met with on the sandy shores.

Chlorophytum attenuatum, Baker, and *C. tuberosum*, Baker, are met with here and there in the plains all over South India.

Characters of the Order.—Plants of this family are mostly herbs, with fibrous roots, bulb, corm, or creeping rhizome. Leaves are alternate or whorled. Flowers are bisexual, regular and the inflorescence is varied. The perianth is petaloid, usually six-lobed in two whorls. Stamens are six with long anthers. Ovary is superior three-celled. Fruit is three-celled, capsular or berried. Seeds are flattened, and with endosperm.

This order differs from Amaryllideæ in having its ovary superior instead of inferior and in other respects there is much resemblance between these two orders.

COMMELINACEÆ.

The common weeds, *Cyanotis axillaris*, Schultes., and *Commelina benghalensis*, Linn., may be taken as types.

Cyanotis axillaris, Schultes, is a diffusely branching herb, with glabrous, erect and prostrate branches. Leaves are

alternate, sessile, linear or linear-lanceolate, fleshy with ciliated, inflated sheath.

Flowers are clustered in the axils of leaves, within the *inflated leaf sheaths: bracteoles are linear. There are three* lanceolate sepals and the corolla is tubular with three broadly ovate lobes, violet or violet-blue. There are six perfect stamens and the filaments are swollen at the apex, bearded. The ovary is three-celled with two ovules in each cell.

The fruit is a capsule, oblong, beaked and glabrous. Seeds are compressed, oblong truncate at base and with a conical tip at the apex, brown, rough and beautifully pitted.

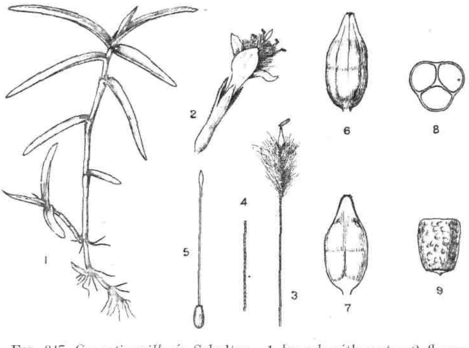

FIG. 347. *Cyanotis axillaris*, Schultes. 1, branch with roots; 2, flower; 3, stamen; 4, hair on the filament; 5, pistil; 6 and 7, fruit; 8, fruit cut across; 9, seed.

Cyanotis cucullata, Kunth., is another species met with as a weed in cultivated lands. It differs from *C. axillaris* in having almost naked filaments and a fruit broad at the apex and this plant is more robust.

Commelina benghalensis, L., is a slender, diffusely and dichotomously branching herb, with creeping and rooting branches. Leaves are alternate, oblong or ovate-oblong, sessile or short-stalked, base unequal sided, sparsely hairy on both

sides. Flowers are enclosed in spathes, funnel-shaped, and *are in scorpioid cymes. Sepals are three, small, oblong.* There are three blue petals. Stamens are six, three or four being perfect and the others reduced to staminodes. The ovary is superior, three-celled with two cells two-ovuled and the third one-ovuled. The fruit is a capsule, pyriform with five seeds. Seeds oblong, closely pitted. In this plant are found cleistogamous underground flowers, which develop fruits with one or two large seeds.

Another genus Aneilema is also very well represented in South India. They are very common in wet situations such as borders of tank beds, paddy flats and ditches. This genus has flowers in panicles without spathes. Flowers are violet or pink. The common species are *Aneilema spiratum*, R. Br., and *A. nudiflorum*, R. Br.

Characters of the Order.—Plants are all herbs, mucilaginous. *Leaves are usually veined distinctly, and with sheathing* bases. Flowers are bisexual, in scorpioid cymes or cymose panicles ; the perianth consists of the two whorls, sepals and petals, three each. Petals are clawed, two being larger than the third. Stamens are six, all are perfect or only three, the remainder being staminodes. Ovary is two or three-celled. Fruit is capsular or indehiscent. Seeds are angled and endospermic.

PALMEÆ.

The Coconut palm is a tall tree with a straight stem, which is thickened at base, annulate and varying in height from fifty to eighty feet. Leaves are very large with a very long petiole expanded at the base where it clasps the stem, pinnately compound ; leaflets are equidistant, linear, coriaceous. Flowers are unisexual, monœcious, in a branched spike, enclosed by a large spathe. Female flowers are few, large, towards the basal portions of the branches of the spike, and sometimes with a male flower on each side : there are two broad bracteoles. The perianth consists of three sepals and three petals, all accrescent. The ovary is superior and three-celled. The male flowers have three very short sepals and three oblong petals both being valvate. There are six stamens. Pistillode is present, but sometimes absent,

The fruit is a fibrous drupe, with a single massive seed, which consists of a huge mass of endosperm enclosing a cavity filled with a liquid (coconut milk) and a small embryo embedded in the endosperm.

The date palm, *Phoenix sylvestris*, Roxb., *Calamus Rotang*, L., *Borassus flabellifer*, L., *Areca Catechu*, L., are some of the other palms in South India.

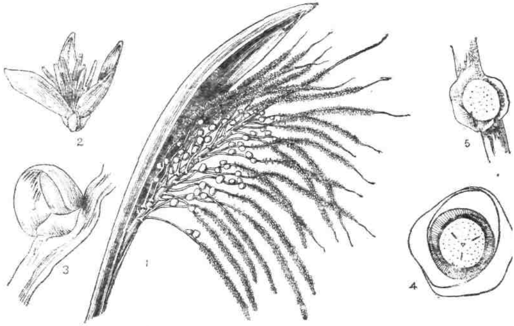

FIG. 348. *Cocos nucifera* 1, spathe and spadix; 2, male flower; 3, female flower; 4, female flower cut across to show folding of petals and sepals; 5, bract and bracteoles at base of female flower.

Characters of the Order.—Plants of this order are shrubs or trees, with stems erect, or scandent. Leaves are alternate with sheathing petioles, plicate in bud, pinnatisect or palmate. Flowers are small, bisexual or unisexual. Sepals and petals are three each. There are usually six stamens and rarely many; filaments are free and anthers are versatile. Ovary is one to three-celled. Fruit is a drupe or a hard berry. Seeds have a small embryo and usually ruminate endosperm.

AROIDEÆ.

Colocasia Antiquorum, Schott., is a good example. It is a coarse herb with rhizomes and corms. Leaves are simple,

with a sheathing petiole ; the blade is peltate, ovate with a broad triangular sinus at the base. Flowers are unisexual, borne by a spadix which is shorter than the spathe enclosing it. The spadix has an appendage. Male flowers are above and female flowers below with neuters between. The male flower consists of only the stamens and the female of the pistil only. Fruits are berried.

This is a very well defined order in which the flowers are reduced to their essential organs, the stamens and the pistil and they are borne by a spadix enclosed by a spathe.

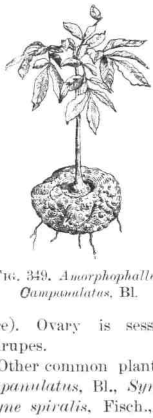

FIG. 349. *Amorphophallus Campanulatus*, Bl.

The plants are perennial herbs or scandent shrubs. Leaves are alternate with a petiole having a sheathing base ; blade is entire or lobed in various ways. Flowers uni- or bisexual, monœcious. Male flowers are towards the apex of the spadix and females at the base of the spadix, often with neuters between them and sometimes with neuters above the males Perianth is absent. Stamens in male flowers one (in bisexual more). Ovary is sessile three-celled. Fruits are berries or drupes.

Other common plants of this order are *Amorphophallus campanulatus*, Bl., *Synantherias sylvatica*, Schott. *Cryptocoryne spiralis*, Fisch., *Pistia Stratiotes*, L., *Typhonium trilobatum*, Schott., *Pothos scandens*, L., and *Theriophonum crenatum*, Bl.

CYPERACEÆ.

Cyperus rotundus, L., a troublesome weed of cultivation is a good representative of this family.

The plant consists of many underground stolons bearing fragrant tubers and a few aerial branches terminating in inflorescences. Leaves are grass-like, three-ranked, mostly crowded at the base of the stem, with closed tubular sheaths,

Inflorescence is an umbel of spikelets. A spikelet has ten to fifty glumes distichously arranged, and the flowers are in the axils of glumes. Flowers consist of three stamens and an ovary with a three-fid stigma, and there is no perianth. The ovary is superior one-celled. The fruit is a broadly ovoid, trigonous, blackish nut.

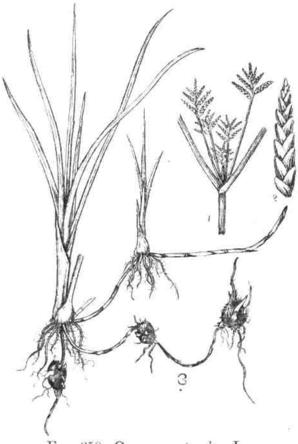

FIG. 350. *Cyperus rotundus*, L.

1, inflorescence ; 2, spike ; 3, stolon with tubers.

Fimbristylis miliacea, Vahl., is a common sedge of the wet lands. It is an annual with tufted stems. Leaves are shorter than the stem and their sheaths are distichously arranged. Spikelets are in compound umbels, globose, with closely imbricating ovate, boat-shaped glumes. Stamens vary from one to three. Fruit is a nut, obovoid, yellowish and tuberculate. The style is three-fid.

Characters of the Order.—The plants of this order are mostly herbs with the habit of grasses. Stem is rounded or

triquetrous. Leaves are grass-like, but the sheath is closed : three ranked and without any out-growth at the junction of the blade and the leaf-sheath. Flowers are bisexual, arising from the axils of bracts (glumes), and consist of only stamens and an ovary. The perianth is absent but sometimes as rudimentary scales, bristles, etc., because the function of protection is done by the glumes. The inflorescence consists

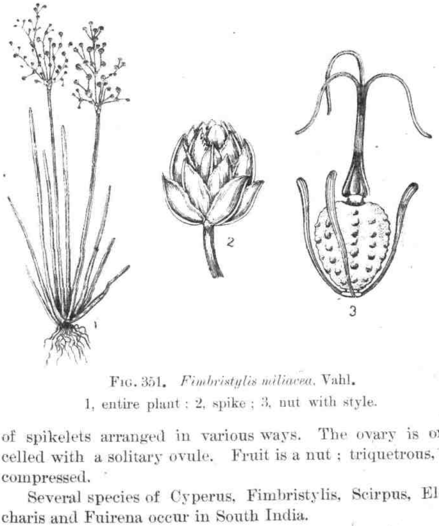

FIG. 351. *Fimbristylis miliacea*, Vahl.
1, entire plant : 2, spike ; 3, nut with style.

of spikelets arranged in various ways. The ovary is one-celled with a solitary ovule. Fruit is a nut ; triquetrous, or compressed.

Several species of Cyperus, Fimbristylis, Scirpus, Eleocharis and Fuirena occur in South India.

GRAMINEÆ.

Panicum javanicum, Poir., a common grass flourishing in damp situations may be examined as a type.

It is a herb with prostrate branches, rooting below, and geniculately bending upwards. Leaves are alternate, with a

loose softly hairy sheath, split open on one side ; the blade is parallel nerved, ovate-lanceolate, acuminate and semi-amplexicaul at base. At the junction of the blade with the leaf-sheath, there is a ridge of soft hairs and this is the ligule, a structure peculiar to grass-leaves. The inflorescence is a panicle of spikelets. The spikelets are biseriate, ovoid with

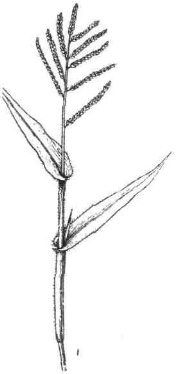

FIG. 352. *Panicum Javanicum*, Poir. 1, branch.

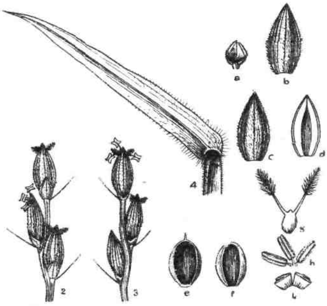

FIG. 353. *Panicum Javanicum*, Poir. 2, 3, spikelets : 4, leaf blade : 5, pistil : 6, anthers : 7, lodicules, *a*, *b*, *c*, *e*, glumes : and *d* and *f*, palea.

very short, pubescent pedicels. The spikelet consists of four glumes : the first glume is very small, broadly ovate, less than half the length of the third glume, three to five-veined, the second is ovate acute, seven-veined, the third is broader, five-veined, with a palea and sometimes even with three stamens and the fourth is oblong rugose tip rounded and with a mucro and a crustaceous palea. Generally the first three glumes are empty, the third glume alone enclosing a bisexual flower. Outside the stamens and within the glume and the palea two small cuneate fleshy bodies are seen. These are called *lodicules*, and they are considered to be the rudimentary perianth lobes. The ovary is one-celled

with two plumose stigmas. Fruit is a grain enclosed by the fourth glume and its palea.

Andropogon Sorghum, L., the cholam plant may be studied as a second type.

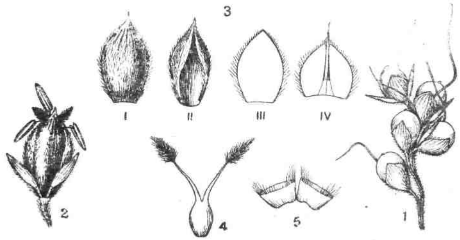

FIG. 354. *Andropogon Sorghum*, L. 1,2, spikelets; 3, parts of the spikelet; i—iv, glumes; 4, pistil; 5, lodicules.

It is a tall plant, usually with a solid single erect stem with aerial prop roots. Leaves are alternate, bifarious and large, with a distinct hyaline ligule with a ciliated margin. The inflorescence is a mass of spikelets in a close or open panicle. There are two kinds of spikelets, the sessile and the pedicelled. The sessile one has four glumes: the first and the second are equal and somewhat coriaceous and hard, the third and the fourth glumes are thin and delicate and smaller than the second; the fourth glume is sometimes awned. Between the fourth glume and its palea there is a complete flower and the third glume has in its axil three stamens. The complete flower consists of three stamens, two lodicules and an ovary with two feathery stigmas. In the pedicelled spikelets also there are four glumes and they are barren. The fruit is a grain.

Eleusine ægyptiaca, Desf., a common fodder grass may be taken as a third type.

It is an annual with many prostrate branches, rooting at the nodes, compressed and glabrous. Leaves are linear, glabrous or with a few hairs with a ligule of hairs. The inflorescence consists of four or more spikes borne palmately

at the top by a peduncle. The spikelets are biseriately arranged on one side of the axis of the spike, and each spikelet has five to seven glumes. All the glumes except the first two contain complete flowers (stamens and ovary). The *floral glumes* have three nerves and a two-nerved palea. There are two small cuneate lodicules. Fruit is a grain, free.

Other Panicums met with in South India are *P. colonum*, L., *P. prostratum*, Lamk., *P. ramosum*, Linn., and *P. crus-galli*, L., and all these grow in a wild state. Some of the Panicums are also cultivated and they are *P. miliaceum*, *P. miliare* and *P. frumentaceum*.

The genera, Setaria, Andropogon, Chloris, Aristida, Eragrostis and Sporobolus are well represented in South India.

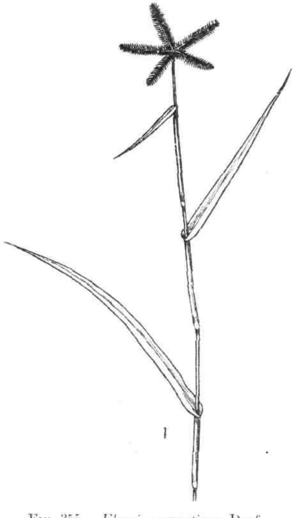
FIG. 355. *Eleusine ægyptiaca*, Desf. A branch with inflorescence

Characters of the Order.—All plants of this order are herbs, except the sugarcane and bamboo. The stem is round or compressed, hollow or solid. Leaves are alternate, two ranked, parallel-veined with a sheathing base or the leaf-sheath and a blade. The sheath is usually slit open on one side and at the junction of the sheath with the blade, there is a ligule which is either membranous or a fringe of hairs. The flowers are reduced to the essential organs, stamens and the pistil, the perianth being represented by two very small

fleshy cuneate bodies, *the lodicules*. The bracts grow larger and afford protection to the flower and so these are called *glumes*. The flowers are sessile on the axis (*rachilla*) and are enclosed by the glumes. The glumes and the flowers are grouped into small compact spikelets and a spikelet, which may consist of four or more glumes distichously arranged, is generally taken as the unit of the inflorescence in grasses. The first two glumes of a spikelet are empty and succeeding glumes are floral glumes. The flowers arise from the axils of glumes and have on the other side a hyaline two-nerved scale called *palea*. The spikelets are in panicles, racems, or spikes, and they are simple or compound. Stamens are usually three with slender filaments and versatile anthers. Ovary entire, one-celled, with two plumose styles. Fruit is a seed-like grain, free or adnate to the flowering glume and palea.

FIG. 356. *Eleusine ægyptiaca*, Desf.

2, leaf blade ; 3, 4, spike ; 5, spikelet ; 6, parts of a spikelet.

Of all the natural orders this order is the largest and most widely distributed over the world. All the cereal grains, the staple foods of the mankind, Wheat, Rice, Ragi, Cholam, Millets, Maize are members of this family. From an economic point of view this order is a most important one. Many grasses are valuable as fodder for cattle.

CHAPTER XIX.

PLANT ECOLOGY AND PLANT FORMATIONS.

FOR systematic classification plants are viewed as separate units, and the floral characteristics form the basis for classification. The object of systematic grouping is to show the relationship and this has nothing to do with the life and habits of the plant. Plants may be viewed from a different standpoint of view, i.e., according to their environment or habitats. If we look at the vegetation of any particular locality as a whole, we find many species of plants growing together. On close examination it will also be seen that the plants belong to diverse groups having no relationship whatsoever. This intermingling of plants may be considered to be the result of accident. That it is not due to sheer chance is obvious from the fact that in similar localities we find, more or less, the same groups of plants with very slight variations, if any. Every species of plant tries its level best not only to live well, but also to increase its progeny and expand to its utmost capacity. And there will be a keen struggle amongst different species, and naturally only those species that are best fitted for the locality are likely to get established. As an ultimate result of this struggle, different species of plants not genealogically related may acquire similar habits and become ecological groups. Groups of plants that give a distinctive feature to a locality are called "formations."

A successful living on the part of a plant indicates a harmonious relation between it and the physical factors amidst which it happens to grow. We know that a green plant is able to nourish itself, but this process is subject to the control of its environment. For the proper development and growth of a green plant oxygen, water, carbon dioxide, a certain amount of heat and a suitable substratum are essential. These factors act on the plant as so many stimuli and it responds readily, and it must be remembered that the response of a plant to the factors of its environment is always

functional. Plants do very well so long as the intensity and amount of each of these stimuli does not rise above or fall below certain limits. For example, in plants that receive the optimum quantity of oxygen, light, carbon dioxide and water, growth is very rapid. If, on the other hand, these factors are below the optimum, it gradually decreases and may finally even cease. Generally the maximum and minimum limits of the chief factors are not close, but far apart and, therefore, plants growing under normal conditions are able, in many cases, to prolong their lives even when these conditions have undergone modification in one direction or other; and if they possess powers of adaptation to changed conditions, they manage, at first, to live somehow, and later on they get well established. A plant that is unable to adapt itself to the most pronounced factor or factors of its environment, when such factors change, becomes extinct.

Plants growing in a particular place have to adjust themselves constantly to the various stimuli affecting them. So long as these stimuli are normal, responses on the part of the plant consist in mere normal adjustment, that is, necessary for their ordinary activity. For example, when the atmosphere becomes dry and at the same time somewhat hot, the leaves change their position and the stomáta become closed. But as soon as these adverse conditions pass off the leaves resume their normal position and the stomata remain open. If, on the other hand, the dryness increases and the atmosphere remains dry without returning to its original condition, the adjustments on the part of the plant must become most pronounced and there will also be certain structural changes. So whether a plant responds by ordinary adjustment or by adjustment along with structural changes depends upon the nature of the stimulus. When the stimulus is of ordinary intensity the plant responds by its usual functional adjustments, without any change in structure, whereas on the stimulus becoming unusual in intensity or nature the response is an adaptation, i.e., adjustment coupled with some structural modifications.

In a plant it is only the vegetative organs that are affected to a marked degree, by the factors of its environment, and the reproductive organs or the parts of the flower are not at all

influenced in any way. Sometimes the influence exerted by the factors are so profound as to bring about the same kind of structural and morphological features in the vegetative organs of species of very widely separated families. For example, the three species, *Euphorbia antiquorum*, L., *Boucerosia umbellata*, W. & A., and *Opuntia Dillenii*, Haw., though belonging to three different families have the same kind of vegetative shoot. Another example of this is afforded by the species, *Limnanthemum indicum*, Thw., *Trapa bispinosa*, Roxb., *Nymphaea Lotus*, L., and *Peplidium humifusum*, Delile., belonging to four natural orders that are distant in affinity. The same kind of structural modification noticed in diverse species genealogically wide apart and brought into existence by ecological factors is generally termed a *growth-form*. For ecological classification, growth-forms are the units just as species form the units for the systematic grouping The growth-forms of *Opuntia Dillenii*, *Boucerosia umbellata* and *Euphorbia antiquorum* are quite characteristic of plants growing in a dry place (Xerophytes) and the other plants mentioned are aquatics (Hydrophytes). Plants are usually classified into many ecological groups, but in this book we shall concern ourselves only with the more striking ones.

Hydrophytes or aquatic plants and their characteristics.— Of all the factors of the environment of a plant water exercises the greatest influence on plants. How very far reaching this influence is, becomes obvious, when we compare a submerged water plant with a land plant. An aquatic like *Vallisneria spiralis*, L., or *Hydrilla verticillata*, Casp., or *Ceratophyllum demersum*, L., is very limp and delicate and so, incapable of remaining erect when taken out of water. This flaccidity is due to want of xylem and other hard tissues, so common in land plants. All submerged plants are, more or less, alike in several respects, and this is due to the fact that the conditions of living are more uniform under water than in air. Another characteristic feature of water plants is the possession of large air spaces in abundance. Both these characteristics, viz., the presence of air cavities and the absence of xylem tissue lead to the lessening of the specific gravity of the plant. Further, water being denser than air, by itself it will support the weight of the plant.

A land plant gets mineral salts from the water contained in the soil and the gases from the atmosphere, whereas a submerged plant depends for everything on water. Consequently the absorbing organs, roots and root hairs and the conducting tissue or xylem, so essential for a land plant, become superfluous in the case of aquatics. However, where roots and root-hairs are present, they are helpful in fixing the plant to its substratum. As water plants are not subjected to the strains due to wind and weight to which the shoots of land plants are exposed, the need for mechanical tissue does not exist, and the required support is afforded by water in a thorough manner. However, like roots, the shoot systems of aquatics are subjected to longitudinal strain caused by movement of water, and to resist this longitudinal pull, the few xylem elements present in the stem are found arranged axially, i.e., as near to the centre of the stem as possible.

The air spaces in water plants, besides helping them to float, facilitate, the process of respiration. A submerged plant is unable to get oxygen as readily and as easily as a land plant, because water does not absorb oxygen in large quantities. The air spaces convey oxygen to all parts that are submerged. In the case of plants growing in salt swamps and marshes oxygen cannot be obtained with ease, because water absorbs only a limited quantity of oxygen. To overcome this difficulty, plants growing in salt swamps have breathing roots or pneumatophores. In marsh plants a special tissue called ærenchyma is formed from the phellogen layer either in the roots as in the case of *Jussiaea suffruticosa* and Sesbania, or in the stem as in *Neptunia oleracea*, etc. Some free, floating plants growing in stagnant water and marshes, have leaves with finely divided blades and this leads to the increase in the absorbing surface.

A submerged water plant is able to absorb water through all its parts. The epidermis needs no cutin and stomata are also unnecessary. As light passes through water on all sides the leaves are, like shade leaves, without any distinction into palisade and spongy parenchyma. The epidermis also contains chloroplastids.

The aquatic mode of life is highly advantageous for rapid growth, because water can absorb large quantities of

carbon dioxide, and plenty of water, salts and oxygen also are available for the plant. Thus favoured, these plants grow rapidly, multiply and extend very quickly, by means of *vegetative reproduction.*

It is a well known fact that humidity and abundance of food material always tend to favour the growth of vegetative organs and prevent the formation of sexual organs, whereas dryness favours the formation of sexual organs. So in water *plants vegetative multiplication far exceeds the sexual reproduction,* and some species such as Elodea and Lemna multiply solely by vegetative propagation. In cases where flowers are produced, as in *Vallisneria spiralis* and *Hydrilla verticillata,* special adaptations exist to bring about pollination. The female flowers are borne on long stalks and so they come up to the surface of the water to get pollinated. Male flowers get detached and float in large numbers, which must necessarily bring about pollination.

A great majority of water plants are submerged plants. Of these some are free swimming and others fixed to the substratum. Most of the species of the order Hydrocharideæ are aquatics fixed to the soil and plants like Ceratophyllum and Utricularia, float and are carried about freely in water.

The leaves of aquatics that are submerged are delicate and thin, and they show considerable amount of variation. Plants growing in situations where water is always still without disturbance, have large leaves (e.g., *Ottelia alismoides*). The leaves of plants subjected to movements of water have either ribbon shaped leaves (e.g., Vallisneria) or their leaf blades are divided into small linear segments (e.g., Ceratophyllum and Utricularia).

There are also some aquatics whose leaves always float on the surface of the water, as in Nymphæa, Aponogeton and Limnanthemum. The leaves are in this case thick with continuous margin and plenty of cuticle or wax on the upper side. Large number of stomata are also found on the upper surface.

Lastly we have a large number of plants growing in marshes and edges of ponds and tanks. In all these plants, a portion of the shoot system is submerged and the remaining portion is aerial. Leaves that are submerged differ very much

from the aerial leaves (e.g., several species of Limnophila). The possession of aerial leaves enables these marsh plants to grow even in stagnant pools and ditches.

Xerophytes or plants of dry regions.—Ordinary land plants depend upon the soil for their water, and they do well so long as there is an adequate supply. When a plant gets a liberal and uniform supply of water it produces leaves with large thin blades, softer less woody parts and very few protective appliances. Plants growing in thick moist forests are of this kind. In all tropical forests with a heavy rainfall, great luxuriance of vegetation is the prevailing condition. If water becomes scarce in a tropical region the vegetation suffers very much and it becomes stunted.

The organisation of a land plant is such as to ensure a regular flow of a rapid current of water from the roots to the leaves and constant transpiration from the leaf surface. The structure, position and arrangement of leaves are intended to facilitate transpiration. If for any reason the roots are unable to absorb water freely, the plant will suffer unless the transpiration that may be going on is prevented. In moderately dry places, as a rule, the plants manage to lower the transpiration by various means. If the period of drought is not long, there will not be very great change in the plant, beyond mere adjustment. On the other hand, plants growing in places where there is a prolonged drought, get modified in various directions, and although of widely different families they all become remarkably similar and we get definite growth-forms.

The xerophilous plants present three types of growth-forms in South India. Many xerophytes have deep roots and when water becomes scarce in the upper layers, they go deeper still to obtain water from the underlying moist layers. At best it can only absorb small quantities of water, and this has to go to the leaf rapidly without much loss. Hence the stem is woody with very narrow cortex.

At the same time the loss of water taking place in the aerial part of the plant on account of transpiration should be minimised. So the leaves become smaller and fewer in number, the cutin of the epidermis becomes very thick and the stomata decrease in number, and instead of being flush

with the epidermis lie deep in furrows. Cork layers are also formed in the stem. As an example for this we may mention *Indigofera trita.* Other plants of a similar nature are *Desmodium biarticulatum, Indigofera aspalathoides, Justicia tranquebariensis* and *Stylosanthes mucronata.*

Another class of xerophytes is the one typified by Boucerosia or the Prickly Pear. Plants of this sort have only *fibrous roots and so they are able to take in* water, available in the upper layers of the soil. When the soil is somewhat moist these plants absorb water greedily and store it inside the plant in special parenchyma called water-tissue. As transpiration has to be reduced to its minimum, leaves are not formed and even when formed they are minute and drop off after some time. The stem becomes fleshy on account of *the water storage tissue and to prevent the loss of water the* epidermis of the stem gets a thick coating of cutin and the stomata are greatly reduced in number and they lie deep in furrows.

Another type of xerophyte is the one in which the leaves become fleshy and thick, as in Agaves and Aloes. The leaf instead of the stem becomes the store-house for water. All the arrangements that usually check the transpiration are developed and the leaves are close set. In both the types represented by Agave and Boucerosia, the plants have the *water stored in them thickened by mucilage, another device* to check undue evaporation.

Although the modifications in xerophytes are very varied, yet they all have the same purpose, viz., the prevention of loss of water by excessive transpiration. Leaves being the organs most concerned in this work they are the first to be affected under unfavourable conditions. There are all gradations between a normal land plant *growing in shade and a* pronounced xerophyte.

Halophytes or plants of saline soil.—The xerophytic growth forms already mentioned are evoked by a dry soil. Roots of these plants are unable to absorb water in large quantities because of the scarcity of water. There are a number of plants whose roots do not absorb water freely, although it may exist in abundance. Plants flourishing in salt swamps and saline soils take in water very slowly and

sparingly, otherwise the salt in the water will poison the plants and ultimately lead to their death.

Halophytes present a great similarity in habit and other respects to the xerophytes, and in this group we have another example of plants of distant affinities, in which the environment evokes *similar characteristics, so that they may become* adapted for their surroundings. Ordinary xerophytes of the dry regions suffer from physical drought and halophytes are subjected to physiological drought. In both the cases the effect of the environment on the plant-body is similar. So halophytes constitute one form of xerophytes.

As salt water acts lethally on the plants when freely absorbed, halophytes are obliged to take water in small quantities. Arrangements for the reduction of transpiration is also an absolute necessity in the case of these plants.

In South India on both the East and West Coasts we have salt swamps and saline flats. The land in close proximity to the sea and at the mouths of rivers in backwaters, get submerged daily by the tide and will be exposed only at low water. The soil in these situations consists of clay or clay and sand saturated with water and reeking with foul odour on account of decaying organic matter. There will be no air in this mud. Even such a soil supports vegetation of a particular type, which is called "mangrove formation." This type of vegetation is very interesting in some respects. Most of the plants are low trees or shrubs with their trunks and branches supported by numerous, crooked, irregular prop roots, as if on stilts. These prop roots are spongy in structure and are full of air spaces. Some roots have large lenticels and other arrangements to facilitate the absorption of air. Some species of plants, like *Avicennia officinalis* and *Sonneratia acida* have special respiratory roots, which stand out erect above the ground in rows all around the trees. As the absorption of water is slow, transpiration must of necessity be checked very much. So the leaves of mangrove trees are usually thick, succulent with close set several layered parenchyma and also with water storing cells in some species. The seeds of mangrove if allowed to fall in the mud will never germinate. So in these plants seeds germinate, while the fruit is still attached to the plant. The embryo plant goes on absorbing food material from the parent plant until it develops into

a large seedling. The seedling in many species consists of a long club-shaped radicle with lateral roots and a hypocotyl with a short shoot. These seedlings look very much like long pods. When fully formed they drop off and the club-shape and the pointed end enable them to pierce the mud. Or if they happen to fall on water, they float and get stuck in holes at the earliest opportunity.

As we recede from the mangrove formation we find number of other species of plants. In nooks and corners and in wet places near the backwaters the herb Acanthus ilicifolius grows in abundance. Here and there we find Pandanus lifting its head from amidst Acanthus. Further away in flats that are distinctly saline we meet with several species of Suædas and Salicornias, *Sesuvium Portulacastrum* and in some places Tamarix also. All these plants are either herbs or shrubs, with pronounced xerophytic features. The flora supported by the dry sand of the sea-shore is also striking although it may merge into the ordinary scrub flora towards the inland. The creeping plants *Cyperus arenarius, Spinifex squarrosus, Lippia nodiflora, Ipomæa biloba, Launæa pinnatifida* are abundant though they lie scattered. On the West Coast we have also some trees and shrubs growing in such situations, such as *Barringtonia racemosa, Hibiscus tiliaceus* and Excœcarias.

Epiphytes are a group of plants living under very peculiar conditions. They attach themselves to other plants by means of aerial roots, but without abstracting anything from the latter. On account of this unusual position, obtaining food and water must be a matter of very great difficulty. But they have managed to overcome this difficulty in a variety of ways. For example, many of the epiphytic orchids and aroids growing in South India possess aerial roots specially adapted for the absorption of water. These aerial roots are white in appearance owing to the formation of a kind of sheath consisting of several layers of empty cells strengthened with thickenings here and there. This sheath is called *velamen* and it acts as a sort of sponge in absorbing water rapidly, whenever there is rain.

As the sources of supply of water for epiphytes are dew, mist or rain, it is evident that they can at best have only a

precarious supply at long or short intervals. Therefore we should expect these plants not only to be very sparing in the use of water but also to have arrangements for the storage of water.

The epiphytes also, like land xerophytes, have to endure prolonged droughts and consequently they have many structural features in common. And these structural features are those of pronounced xerophytes.

From what was said above, it is clear that epiphytes cannot live in places where the climate is very dry; but they can live where the atmosphere is likely to be humid at least for some months. On the East Coast of South India we do not find many epiphytes, but, on the other hand, on the West Coast they are abundant. The frontispiece shows a photograph of a Peepul tree abounding in the epiphytes, *Vanda Roxburghii* and *Drynaria quercifolia*.

Mesophytes are the ordinary average plants thriving in a soil of moderate humidity and they avoid the soil with standing water or water containing a high percentage of salts. These plants occupy an intermediate position between the xerophytes on the one hand and the hydrophytes on the other and are abundant in regions where the rainfall is evenly distributed.

In the previous chapters of this book we have been dealing with the structure and function of seed plants, and most of it has reference only to the mesophytes. The leaves of these plants are specially adapted for rapid transpiration and so they are usually large and far more varied in form than xerophytes. The special tissues such as ærenchyma or water storage-tissue are not usually found in these plants. All the plants that abound in the forests of the hills of South India consist mostly of mesophytes.

The vegetation of this Presidency is most interesting as we find in it all kinds of formations. On the sea coast we have the mangrove and salt loving plants. This is succeeded by the sand binding xerophytic plants such as Spinifex, Ipomœa biloba, etc., and this gradually merges into the scrub jungle. The vegetation on the Deccan portion consists of scrubby jungles, and deciduous forests. All the thick evergreen forests are confined to the higher hills and the Western ghats.

GLOSSARY.

A

Accessory fruits, fruits reinforced by stem, or other structures as in Jack fruit, apple, etc., 204.

Achene, one-seeded, dry, indehiscent fruit, 207.

Acuminate, applied to the apex of a leaf when it is prolonged into a fine point, 108.

Acute, applied to the leaf apex when it is pointed without being drawn out, 108.

Adventitious, arising at unusual places : as buds at other places than nodes or roots at places other than roots, 22, 31, 235.

Aerial roots, roots that develop in the air, 56.

Aestivation, applied to the folding in of the sepals and petals in the bud, 173.

Aggregate, forming a dense cluster: applied to fruits formed of a flower and with free carpels, 210.

Ala (pl. alae), the lateral petal of a papilionaceous corolla or the wing-petal, 163, 173.

Aleurone layer, the special outer layer of regular cells with proteid granules in the grains of grasses, 26.

Alternate, at intervals one after the other : said of leaves when they arise singly at the nodes, 100.

Andrœcium, stamens of a flower collectively.

Annular (vessels), having thickenings disposed in the form of transverse rings, 38, 39.

Anther, the portion of the stamen which contains the pollen-grains, 7.

Apocarpous, applied to fruits when the carpels are quite free from each other, 178.

Aril, an appendage on the seed arising from the stalk or from the micropyle, 215.

Auricled, said of leaves with basal lobes shaped like an ear, 107.

Axil, the angle formed by a leaf with the stem on the upper side, 5.

Axile placentation, applied to an ovary when the ovules are attached to the central axis, 178, 179.

Axillary bud, a bud arising in the axil of a leaf, 64.

B

Bacterium (pl. Bacteria), lowest very minute plants devoid of chlorophyll, 1, 59, 144.

Bacterial nodules, swellings formed in the roots of leguminous plants by bacteria which are able to fix the free nitrogen of the air, 59.

Basifixed (or innate), applied to anthers when attached at the base, 176.

Berry, a fruit with a pericarp fleshy throughout, 205.

Bisexual, said of a flower with both stamens and pistil, 160.

Botryose (or racemose), applied to an inflorescence in which the flowers develop in regular acropetal succession, so that the older flowers are at the base and the younger at the top, 154.

Bract, *reduced leaf subtending a flower or an inflorescence*, 110, 151.

Bracteole, *a small bract placed below the flower* on the pedicel, but not subtending it, 162.

Bud, an undeveloped condensed shoot, all the parts being very young and small and the more delicate younger parts being protected by the older parts, 63, 64.

Bulb, a modified underground shoot having a short flat stem with numerous roots below and scaly leaves and buds above, 72, 74.

C

Caducous, applied to sepals or petals falling off very early, 171.

Callus, mass of cells formed on cut or exposed surfaces by the active division of cambium and parenchyma, 95.

Calyx, the outermost whorl of a typical flower ; the sepals collectively, 7.

Cambium, the layer of living cells lying close to the wood in stems and roots which leads to the secondary thickening of stems and roots, 42, 78, 80.

Capitulum, flower-head ; an inflorescence in which the flowers are sessile and crowded at the end of the stalk of the inflorescence, 153.

Capsule, a dry fruit formed of more than one carpel which opens to let the seeds escape, 209.

Carbohydrate, a substance formed out of carbon, hydrogen, and oxygen, the two latter being in the same proportion as in water, 128.

Carpel, a simple pistil, or part of a compound pistil, 178.

Caruncle, a massy outgrowth on a seed near the hilum, as in castor seed, 18.

Caryopsis, a seed-like fruit in which the pericarp and testa are fused together ; applied to the grains of grasses, 207.

Cell, the unit of plant structure or a bit of protoplasm enclosed by a cellulose membrane, the cell-wall, 23.

Cell-sap, the liquid content of a cell having certain salts, sugars, etc., in solution, 25.

Cell-wall, the wall of a cell originally composed of cellulose but altered later on by deposition of other substances, 23.

Cellulose, the substance which goes to form the cell-wall when young and having the same composition as starch, 27.

Centrifugal, from the centre to the periphery ; said of an inflorescence when the order of opening is from the top to the base or from the centre to the periphery, 156.

Centripetal, applied to an inflorescence whereof the flowers are developing from without inwards, as opposed to centrifugal, 155.

Chlorophyll, the green colouring matter of plants contained in chloroplasts, 129.

Chloroplasts, the masses of protoplasm which are of a green colour and found imbedded within the protoplasm of cells of parts exposed to light, 129.

Circulation, the peculiar streaming movement of protoplasm seen in living cells, 149.

Cladophylla or Cladode, flattened stems or branches doing the functions of leaves and sometimes appearing like them, 113.

Cleft, divided about half way in the leaf-blade, 107.

Cleistogamous, said of unopened flowers which are self-fertilised, 188.

Coccus, the dry portion or carpel of a schizocarp or splitting fruit, 207.

Collenchyma, a kind of strengthening tissue beneath the epidermis formed of living cells thickened at the corners, 83, 94.

Compound, said of a leaf whose blade is cut into separate pieces (leaflets) so that one piece (a leaflet) could be detached without injuring others, 6, 108.

Connective, the portion of the stamen which connects the filament with the anther and its lobes, 176, 181.

Conduplicate, folded together, applied to leaf-blades, 98.

Contorted (twisted), said of a corolla in which each petal regularly covers, and is covered by another petal, 174.

Convolute, said of leaves when rolled up along the length from one margin to the other, one being over the other, 98.

Cordate (or heartshaped), applied to a leaf-blade, 107.

Cork-tissue, a kind of protective tissue formed on old stems and roots and also on cut or exposed surfaces consisting of dead cells whose walls are impervious to water and gases 86.

Cork-cambium, a layer of living cells which by active division forms the cork-tissue, 87.

Corm, a modified underground fleshy stem or bases of stems having buds and with or without scales, 73.

Corolla, the petals of a flower collectively, 6.

Corona, an out-growth from the corolla or from the stamens, 173.

Cortex, the portion of stem or root lying between the epidermis and the stele, 38, 79, 83.

Corymb, a flat-topped inflorescence of the racemose type (also applied to cymose type) having the lower older pedicels longer than the upper younger ones, 152.

Cotyledon, the seed leaf or leaves of the embryo plant formed inside the seed, 11.

Crenate, applied to the margin of leaves when it has rounded teeth, 107.

Cross-pollination, transference of pollen to the stigma of a flower from a flower of a different individual, 186.

Cryptogams, flowerless plants ; literally plants whose sexual parts are hidden, 1.

Cuspidate, applied to the apex of a leaf which possesses a small triangular piece, 108.

Cuticle, the outer lining on the epidermis of leaves and stems and formed of the substance cutin which is impervious to water, 79.

Cymose, an inflorescence in which the primary axis ends in a flower and gives rise to branches which repeat the same process ; also termed centrifugal, 156.

D

Deciduous, falling off at the end of the growing season, applied to leaves and petals, 171.

Decussate, arrangement of opposite leaves placed at right angles to each other and forming four rows on the stem, 102.

Definite, applied to cymose type of inflorescence, 156.

Dehiscence, the act of opening of anthers or fruits, 176, 207.

Dentate, applied to the margin of leaves with straight teeth, 107.

Diadelphous, said of stamens united by their filaments into two bundles, 164.

Diastase, the enzyme or ferment which converts starch into sugar, 25.

Dichasium (dichotomous cyme), a cymose inflorescence with branches arising in pairs, 156.

Didynamous, said of stamens, when there are two pairs of them, one pair longer than the other, 175.

Digitate (or palmate), applied to a lobed or compound leaf in which all the lobes or leaflets are attached at the end of the petiole, 9, 107.

Dimorphic (or dimorphous), occurring in two forms, 164.

Diœcious, having the sexes separated in two distinct individuals, 168

Dorsal suture, the midrib of a carpel, or its back side, 179.

Dorsifixed (or adnate), fixed on the back ; said of anthers, 176.

Drupe, a fleshy one-seeded fruit having a stony endocarp ; a stone fruit, 205.

E

Egg-cell, the female cell in the embryo-sac which developes into an embryo after fertilisation, 184.

Embryo, the young plant contained in the seed, 11.

Embryo-sac, the cell in the ovule in which the embryo is formed, 184.

Endocarp, the innermost layer of the pericarp, 205.

Endodermis, the innermost layer of the cortex forming a sheath round the stele, 41, 83.

Endosperm, the reserve food stored outside the embryo and within the embryo-sac in seeds, 19.

Endosmosis, passing of a liquid through a membrane into a more concentrated fluid, 121.

Energy, the capacity for doing work, 134.

Energy, kinetic, the energy of actual motion, 136.

Energy, potential, energy not manifested in action, but stored, 136.

Entire, said of a leaf margin which is neither indented nor toothed, 107.

Epicalyx, bracts placed outside the calyx in certain flowers, as in Malvaceæ ; also called involucre or involucral bracts, 162.

Epicarp, the outermost layer of the pericarp in a fruit, 205.

Epigeal, said of cotyledons coming out of the ground in germination, 20.

Epigynous, applied to a flower in which the other parts rise from above the ovary, as the result of the fusion of the hollow receptacle with the pericap of the ovary, 175, 176.

Epipetalous, applied to stamens arising from the corolla tube, 175, 180.

Epiphytes, plants growing on other plants for the sake of attachment but not parasitic, 57.

Exodermis, the thickened layer or layers of cells beneath the piliferous layer of roots, 49.

Exosmosis, flow of a fluid outwards through a membrane into a less dense fluid, 121.

Extrorse, said of anthers when they open outwards, i.e., towards the petals and away from the pistil, 177.

F

Fertilisation, the fusion of the germ-cell of the pollen-grain with the egg-cell in the ovule which leads to the formation of an embryo, 7.

Fibres (or sclerenchyma), long, narrow, thick-walled cells tapering at both ends found in the mechanical tissue of plants, and without any contents, 41.

Filament, the stalk of the stamen, 7.

Follicle, the free dry carpel of an apocarpous fruit opening at the front or ventral suture only, 208.

Free-central placentation, attachment of the ovules to an axis in the fruit which is not connected with the wall of the ovary but arises from the bottom of it ; also called basal placentation, 178.

Fruit, ripened ovary with its contents, 204.

G

Gamopetalous (or Monopetalous), applied to corollas having petals united together, 166.

Gamosepalous (or Monosepalous), applied to a calyx with united sepals, 163.

Gametes, specialised bits of protoplasm whose fusion is necessary for the formation of seed, 231.

Geotropism, movement in parts of plants in response to the stimulus of gravity, 147.

Geotropism, negative, turning away from the earth, as stems, 147.

Geotropism, positive, going towards the earth, as roots, 147.

Germination, the development and emergence of the embryo from the seed, 12.

Glume, the scale-like bract in the inflorescence of grasses and sedges, 171.

Growing point, the growing tip of a stem or root consisting of embryonic cells from which the different tissues arise, 34, 65.

Guard cells, the cells which go to form the stomata and regulate their opening, 115.

Gynandrous, applied to stamens adhering to the pistil, 174.

Gynæcium, pistil or pistils of a flower taken collectively, 177.

H

Hastate, applied to the leaf-blade when its basal lobes are turned outwards, 107.

Haustorium (pl. haustoria), the sucking organ of a parasitic plant which penetrates the host to obtain food, 139.

Head (or capitulum), an inflorescence in which the flowers are sessile, and crowded at the top of the peduncle, 153.

Helicoid cyme, an inflorescence of the sympodial type in which the lateral branches are developed on one side only, 156.

Hermaphrodite, applied to flowers having both the stamens and pistil in the same flower, 160.

Hesperidium, a superior syncarpous berry, like the orange, formed of many carpels and covered by a tough rind, 206.

Hilum, the scar left on the seed by the funicle or placenta to which it was attached, 13 (also applied to the central point or nucleus of a starch grain round which the layers are seen).

Hydrotropism, curvature induced by the stimulus of moisture, 148.

Hypocotyl, the portion of the seedling which is below the cotyledons and above the radicle, 14.

Hypocrateriform, said of the corolla with a long tube and flat spreading limbs ; salver-shaped, 172.

Hypogeal, said of seedlings when the cotyledons lie below ground, 21.

Hypogynous, applied to flowers, when the stamens and the perianth are at the base of the ovary, 175, 180.

I

Imbibition, passage of water through cell-wall and protoplasm by making them more porous, 121.

Imbricate, the overlapping of petals or sepals in such a way that one *or more parts have both their margins completely inside*, 174.

Indefinite, not definite ; when applied to an inflorescence it means, the older flowers are at the bottom or outside and the youngest at the top or centre, 155.

Indehiscent, said of fruits not opening or splitting to shed their seed, 207.

Inferior, said of an ovary surmounted by the other parts of the flower, 175.

Inflorescence, collection of flowers on an axis, 152.

Integument, *the covering of the ovule*, 184.

Internode, the portion of the stem between two nodes or joints, 5.

Introrse, applied to anthers which open inwards towards the pistil as opposed to extrorse, 177.

Involute, leaf edges rolling inwards from both the margins as in the Lotus leaf, 98, 247.

K

Keel, the boat-shaped anterior petals of a papilionaceous flower, 163.

Kidney-shaped, reniform ; applied to organs which are crescent-shaped with rounded ends, 107.

L

Labiate, lipped ; said of a gamopetalous corolla having an upper and a lower lip, as in Leucas, 172.

Lamina, the blade of a leaf, 96.

Lanceolate, shaped like a lance ; applied to a leaf having a somewhat broad base and tapering towards the apex, 106.

Latex tubes, tubes containing a milky juice, as in Euphorbia, 87.

Leaflet, a separate segment of a compound leaf, 6.

Legume, a monocarpellary fruit opening by both the margins, 208.

Lenticel, a spot in the bark intended to facilitate exchange of gases and consisting of loosely arranged cork-cells, 36.

Lianes, applied to large woody climbers, 69.

Lichen, a cryptogam formed of a fungus and an alga, 142.

Lignification, the thickening of cell walls by means of lignin.

Ligule, a structure found at the junctions of the blade and the sheath in the leaves of grasses, 326.

Ligulate, applied to the strap-shaped corolia of the ray florets in the head of a compositæ, 173.

Linear, applied to a leaf, petal or sepal, when it is very long and narrow, 105.

Loculicidal, applied to the dehiscence of a capsule when the opening is by the dorsal or back side so as to expose the cavity, 209.

Lomentum, a legume constricted between the seeds and separating into one-seeded parts, 208.

M

Mechanical tissue, the tissuse which contributes to the rigidity and strength of plant organs, 92.

Medulla (or pith), the central core within the stele of dicotyledonous stems, 76.

Medullary rays, the rows of parenchyma cells which extend from the pith to the cortex, 76.

Meristem, the active dividing uniform cells in plants located in young parts at the growing points, 35.

Mesocarp, the middle portion of the pericarp in fruits, 205.

Micropyle, the hole in the ovule through which the pollen-tube enters in the act of fertilisation ; also the aperture found in the seed coat, 11.

Monadelphous, applied to stamens united together by the filament forming one bundle or a tube, 165.

Monocarpellary, formed of one carpel only, 178.

Monochasium, a cyme with one main axis, 159.

Monœcious, having the stamens and pistil on separate flowers but on the same plant, 168.

Monopetalous, same as gamopetalous.

Monopodial, applied to a stem or axis resulting from the activity of a *single terminal growing point*, 66.

Monosepalous, same as gamosepalous.

Mucronate, having a mucro or a sharp point at the apex of a leaf, 108.

Mycorhiza, fungus found in association with the roots of certain plants either within or without and for the advantage of both, 142.

N

Nectary, an organ which secretes nectar or honey, 192.

Node, the part of the stem whence leaves arise, 5.

Nucleus, the important part of a living cell which is of a denser nature and which initiates the division of a cell, 25.

O

Oblong, applied to a leaf blade or a perianth lobe when it is longer than broad with more or less parallel sides, 106.

Obovate, applied to a leaf blade when it is egg-shaped but with the narrow end towards the base, 106.

Obtuse, said of the apex of a leaf-blade when it is rounded, 108.

Opposite, applied to leaves arising in pairs at the same node, 100

Orbicular (or rotund), said of a leaf having a round outline, 106.

Osmosis, diffusion of fluids through a membrane, 121.

Ovary, the portion of the pistil which contains the ovules, 7.

Ovate, shaped like an egg, the broader end being near the base, 106.

Ovule, the part of the ovary which developes into seed after fertilisation, 184.

P

Palea, the scale-like part which covers the flowers of grasses and this is two-nerved, 326.

Palisade parenchyma, parenchyma consisting of elongated chlorophyll containing cells found below the upper epidermis of most leaves, 116.

Panicle, an open mixed inflorescence, racemose or cymose or both, 159.

Papilionaceous, having the shape of a butterfly ; said of a corolla made up of a standard, two wing-petals and a keel formed of two petals, 173.

Parenchyma, the cellular ground tissue of plants consisting of thin-walled cells.

Parietal placentation, attachment of ovules to outgrowths on the inner wall of the ovary, 178.

Pedicel, the stalk of an individual flower, 162.

Peduncle, the flower stalk of a solitary flower or of an inflorescence.

Peltate, applied to a leaf attached to the stalk on the lower surface instead of at the margin, 246.

Pentamerous, with the parts in fives, 238

Pepo, the fruit of a gourd ; an inferior one-celled fruit with a hard rind and parietal placentation, 206.

Perianth, the floral envelopes, calyx and corolla.

Pericarp, the wall of the fruit, 203.

Pericycle, the ring of cells of the stele just within the endodermis, 42.

Perigynous, said of the flower when the perianth and stamens are placed round the ovary, 176.

Perisperm, reserve food formed in the ovule outside the embryo-sac, 214.

Persistent, remaining for a long time as the calyx on some fruits, e.g., Brinjal, 171.

Petal, part of a corolla usually brightly coloured, 6.

Petaloid, said of sepals when coloured like petals, 165.

Petiole, the leaf-stalk, 6.

Phloëm, the portion of a vascular bundle consisting of sieve-tubes and parenchyma, 42.

Photosynthesis, formation of starch from water and carbon dioxide within the chloroplastids under the influence of sunlight, 129.

Phyllode, a flattened petiole assuming the form and functions of a leaf, 113.

Phyllotaxis (or phyllotaxy), the arrangement of leaves on the stem, 100.

Piliferous layer, the outermost layer of cells in the root which produces the root-hairs, 40.

Pinnate, said of a compound leaf having the leaflets arranged in two opposite rows on a common petiole, 9.

Pistil, the innermost part of a complete flower consisting of the ovary, style and stigma, 7.

Pistillode, an undeveloped pistil.

Placenta, the outgrowth in the ovary which bears the ovules.

Plumule, the part of the axis of the embryo in the seed above the insertion of the cotyledons, 12.

Pneumatophore (or pneumathode), the breathing roots of certain plants such as those of Avicennia, 60.

Pollen, the yellow powdery substance found in the anther lobes, 7.

Pollination, the transference of pollen from the anther to the stigma of the same or another flower, 7.

Pollinium (pl. pollinia), a pollen-mass composed of all the pollen-grains, in a pollen-sac, 199.

Polygamous, having unisexual as well as hermaphrodite flowers in the same plant or species, 168.

Pome, an inferior fleshy fruit in which the fleshy part consists of the receptacle and adnate calyx, 206.

Primary axis, the axis in the embryo which developes into the main stem, 12.

Primary meristem, the formative tissue of a young organ, 43.

Primary medullary rays, the first formed rows of parenchymatous cells which radiate from the pith to the cortex between the vascular bundles, 83.

Procambium, the ring of small embryonic tissue in the stele from which vascular bundles arise, 81.

Procambial strands, bands of tissue in the procambium which ultimately become vascular bundles, 81.

Protandrous, applied to a flower in which the stamens shed their pollen before the stigma is receptive, 188.

Proteid, a complex nitrogenous substance consisting of carbon, hydrogen, nitrogen, sulphur and phosphorus, 131.

Protogynous, applied to a flower in which the stigma is ready to receive the pollen before the anthers are mature, 188.

Protoplasm, the living substance of plants consisting chiefly of proteids, 23.

Pyrene, the small portion of a drupe, 206.

Pyxis, a capsule which opens transversely by the separation of a lid, 210.

Q

Quincuncial, said of the æstivation of calyx or corolla with five parts, two being in, two out and one in and out, 174.

R

Raceme, an inflorescence having a main axis with stalked flowers on it arranged in acropetal succession, 152.

Racemose, same as botryose.

Radicle, the part of the primary axis of the embryo lying below the attachment of the cotyledons, 12.

Receptacle, the dilated end of the flower stalk from which all the parts of the flower arise ; also called torus, or thalamus, 160.

Reniform, same as kidney-shaped, 107.

Reticulate vessels, vessels with thickenings in the form of a net work, 39.

Retuse, applied to the apex of a leaf when it is notched, 108.

Rhizome, a creeping underground stem sending roots down and shoots above, 71.

Root-cap, the structure found at the extreme end of young roots forming a protective covering, 34.

Root-hairs, elongated cells of the piliferous layer in the youngest portions of roots, 34.

Root-sheath, special covering of the radicle in monocotyledonous seeds especially in grains, 20.

Root-sucker, a shoot originating from the root, 30.

Rotate, wheel-shaped ; applied to a united corolla having a short tube and spreading limbs, 172.

Rotation, a peculiar kind of movement of protoplasm, 150.

Runner (or stolon), a prostrate branch which strikes roots and developes shoots, 69.

S

Sagittate, applied to a leaf blade having two straight lobes at the base and shaped like an arrow, 107.

Samara, an indehiscent winged fruit, 207.

Saprophytes, plants that take nourishment from dead organic matter, 142.

Scalariform vessels, *vessels having thickenings in the form of a ladder*, 39.

Scale-leaves, small leaves which are found in underground shoots or stems above ground, 109.

Scape, a leafless peduncle arising from a subterranean stem, 246.

Schizocarp, a dry fruit which splits into separate parts or segments, 207.

Sclerenchyma, tissue consisting of long cells with narrow cavity and very much thickened cell-walls without any protoplasm, 41.

Scorpioid cyme, a cymose inflorescence with the lateral branches developed alternately on opposite sides, 157.

Scutellum, the shield-like structure or cotyledon in the grain of grasses, 20.

Self-pollination, *pollen of one flower reaching* the stigma of the same flower or that of another flower on the same plant, 186.

Semi-parasite, a plant which derives part of its nourishment from another (host), 138.

Sepal, a segment of a calyx, 6.

Septicidal, opening along the septa, or lines of partition of a capsule, 210.

Serrate, applied to the leaf-margin when toothed like a saw, 107.

Sieve-tubes, the rows of long tubes with perforated cross partitions (sieve-plates) found in the phloëm of a vascular bundle, 42.

Spadix, an inflorescence having a fleshy axis with numerous sessile flowers closely packed together, the whole surrounded by a common bract, 153.

Spathe, the large bract enclosing the flowers of a spadix, 153.

Spermophytes, seed-bearing plants ; also called phanerogams, 1.

Spike, an inflorescence in which the flowers are sessile on a long axis, 153.

Spikelets, the small flower clusters of grasses enclosed by scaly bracts called glumes, 324, 326.

Spine, a sharp woody structure regarded as a modified leaf, branch or stipule, 70.

Stamens, the male part of a flower having a filament and an anther, the latter producing the pollen, 7.

Staminode, an aborted or rudimentary stamen, 167.

Standard, the posterior petal of a papilionaceous corolla, 163.

Stele, the central core of tissue and cells enclosed by the cortex in stems and roots, 39.

Stigma, the topmost part of the pistil which receives the pollen, 7.

Stipule, an appendage of the leaf found at the node on either side of the leaf base, 6.

Stomata, minute openings in the epidermis of leaves and young stems which promote the gaseous exchange between the atmosphere and the interior of plants, 115.

Strophiole, an outgrowth on the hilum of some seeds, 215.

Syconium (or fig), a multiple fruit formed of a hollow fleshy receptacle inside which the fruits are placed, 212.

Sympodial, applied to the method of branching in which the main axis ceases to grow and the lateral branches form a false axis, 67.

Syncarpous, said of a fruit when the carpels are fused or united together, 178.

Syngenesious, applied to anthers when they are united together so as to form a tube, the filaments being free, 174.

T

Tap-root, the main root, the continuation of the radicle, 4.

Tendrils, thread-like organs by means of which some plants cling on to their supports, 70.

Tetradynamous, said of stamens when they are six in number, two of them being shorter than the rest, 175.

Thorn, a pointed woody structure regarded as a modified branch, 70.

Tissue, a combination of cells similar in origin and texture, 35.

Truncate, applied to the apex of a leaf when it is straight as though cut off, 108.

Tuber, a modified underground branch which is swollen and fleshy, 71

U

Umbel, a flower cluster in which all the pedicels spring from the same point, 153.

V

Vacuole, a cavity in the protoplasm of cells containing the cell-sap, 25.

Valvate, when sepals or petals meet together without overlapping, 173.

Vegetative reproduction, propagation by vegetative means, e.g., cuttings, buds, etc., as opposed to sexual reproduction, 231.

Velamen, layer or layers of absorbing cells found in the aerial roots of certain epiphytic orchids and aroids, 58, 338.

Versatile, applied to the attachment of the anther to its filament at a point so as to move freely, 176.

Verticillaster, a false whorl formed of many cymes congested together as in Leucas, 158.

W

Wing-petal, the lateral petal of a papilionaceous corolla, 163.

X

Xylem, the wood portion of the vascular bundle, 41.

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